Washington State
Department of Transportation

Memorandum

August 30, 2007

TO: Mike Andreini, P.E.
Development Branch Project Engineer
North Central Region

FROM: T.M. Allen / M. Fish
EEP Materials Laboratory MS: 47365
Geotechnical Division

SUBJECT: SR 28 MP 11.83 to 11.96, 0L-3422
Rock Island Slope Stabilization, Stage 3
Final Geotechnical Report

Please find our geotechnical report attached for the subject project. If you have any questions, please contact Marc Fish at (360) 709-5498 and/or Tom Badger at (360) 709-5461.

TMA:mff

Attachments as stated

cc: J. Roseburg – NCR
M. Reister – NCR

GEOTECHNICAL REPORT

Rock Island Slope Stabilization Stage 3

OL-3422, SR 28, MP 11.83 to 11.96

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August 2007

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INTRODUCTION

This report provides design recommendations for rock fall protection along a portion of SR 28 just south of Rock Island Dam (Figure 1). Between the approximate mile posts of 11.83 to 11.96, there is a nearly vertical, 300 foot high basalt cliff that produces rock fall that lands on the highway (Figure 2). The slope has an irregular configuration with a large overhang and a moderately sloping intermediate bench located on the lower half of the slope. The highway and a heavily used rail line are located between the rock slope and the Columbia River. The existing ditch does not fully contain the rock falls that occur at this site. This slope is included in WSDOT's Unstable Slope Management System database and has a slope numerical rating of 357 points. A conceptual design was prepared in 2000 for mitigating the rock fall hazard. This design entailed draping approximately 180,000 ft^2 of the slope area with cable nets. The design recommendations contained within this report encompass draping the rock slope with two different types of rock fall containment systems.

REGIONAL GEOLOGIC SETTING

Physiography

The project is located within the deeply incised middle Columbia River valley with the adjacent walls rising more than 1000 feet in elevation above the river. The highway is sited approximately 40 feet above the river level. The slope above the highway consists of a 300 foot high, near vertical cut and natural slope in bedrock before breaking to a mid slope portion containing talus that has developed from bedrock cliffs above.

Climate

The average annual precipitation for Wenatchee is 8.57 inches. Precipitation averages approximately 1.25 inches per month November thru January with the probability of receiving 0.01" of precipitation approximately 5% for any day during this time period. Average high temperatures are in the mid 80's (degrees Fahrenheit) in July and August and the average low temperatures are in the mid 20's (degrees Fahrenheit) November thru January. The annual average minimum temperature is 40.6 degrees Fahrenheit and the average maximum temperature is 60.9 degrees Fahrenheit. Snow depth averages between 1 and 5 inches from November thru March with a greatest recorded depth of 29 inches being recorded in the month of December (Western Regional Climate Center).

Geologic Setting

The Columbia River Basalt Group underlies much of the southeastern half of the Wenatchee quadrangle (Tabor, et al., 1982). It was erupted from vents farther east or southeast of the quadrangle. The flow directions, measured chiefly on foreset-bedded lava deltas, consistently show west and northwest flow. The Columbia River Basalt Group is divided into 3 formations, and the basalt at the project site is from the Grande Ronde Formation. This basalt is different from other correlative flows on the Columbia Plateau because the lava flowed into rivers draining the ancestral Cascade Range forming pillow basalts, hyaloclastite, and invasive flows that displaced unconsolidated sediments. The Grande Ronde Basalt is of late-early and middle Miocene age (16.5 to 14 m.y.) and is a fine to medium grained basalt (Tabor, et al., 1982).

A subunit to the Grande Ronde Basalt is the invasive Hammond sill. This basalt is over 400 feet thick and is exposed as vertical cliffs at the project site. Regular joint patterns with tall, well-developed, vertical columns or masses of interlocking blocks are common. The lower zone is usually characterized by large, well defined vertical columns, while the upper zone is characterized by blocks, plates, and relatively smaller columns. A typical hand specimen is finely crystalline, nonporphyritic, and medium gray to dark gray in color (Hoyt, 1961). The local geology map displays the extent of the geologic deposits within the vicinity of the project area (Figure 3).

The project is located within the Yakima Fold Belt, a geologic region consisting of west-trending (N50°W to S50°W) anticlinal ridges and synclinal valleys. The anticlines are generally asymmetrical ridges, and the synclines typically have a gently dipping north limb and a steeply dipping south limb. The fold lengths are varied and range up to 60 miles long with wavelengths as long as 12 miles. Faulting of the anticlines is common and is defined by abrupt changes in fold geometry or by places where regional folds die out and become a series of double-plunging anticlines (Reidel and Campbell, 1989). The local geology map in Figure 3 also displays the extent of the geologic structure at the project site.

During the Pleistocene (2 million to 10,000 yrs b.p.), multiple episodes of cataclysmic floods occurred, which were the result of outbursts from ancestral Glacial Lake Missoula. The Columbia River was a primary channel for much of the flood waters. The Wenatchee Mountains in the vicinity of Rock Island formed a constriction for the escaping flood waters resulting in upstream deposition, incision and erosion at the constriction, and both erosion and deposition downstream. Fine-grained deposits formed in slack water areas during these floods, including low-strength clays masked by recent alluvium and colluvium found just upstream of Wenatchee. During the Holocene (10,000 yrs b.p. to present), active mass wasting on the steep valley wall has resulted in formation of thick deposits of talus below bedrock cliffs.

SITE ENGINEERING GEOLOGY

As inferred from the mapping of Tabor et al. (1982), the rock slope is comprised entirely of the Invasive flow of Hammond, a member of the Grande Ronde Basalt. A boring advanced by WSDOT in 1999 (H-5-99) at the top of the rock slope just back of the slope face encountered basalt its full depth. The rock mass consists of fine-grained, strong, fresh to slightly weathered basalt with an approximate unit weight of 170 lbs/ft^3. Based on observed discontinuities and rock mass conditions in the slope, the basalt can be subdivided into four units (Figure 4).

Rock Units

Unit 1: This unit extends the full length along the top of the rock slope and varies in thickness from approximately 30 to 40 feet. The unit displays crude columnar structure with low persistence and a typical spacing of vertical joints defining blocks up to 6 feet. Other frequent joints cut this unit with apparent random orientation. Numerous joints exhibit apertures of one inch or more, defining potentially unstable blocks within this unit.

Unit 2: This unit is separated from Unit 1 by an undulatory contact. Unit 2 outcrop is not continuous across the entire slope, but has an average thickness of 15 feet. The rock mass is extensively fractured with very low persistent joints of random orientation and characteristically tight aperture.

Unit 3: This unit is the thickest unit, which outcrops the entire width of the slope with approximate thickness ranging from 75 to 100 feet. The unit is characterized by light-dark banding and pervasive columnar jointing (Figures 4 & 5). The dark portion of the banding generally coincides with closely spaced fractures of very low persistence; light zones typically have moderate to wide joint spacing with very low to low persistence. The vertical joint set that defines the columnar structure has typically medium to high persistence and wide spacing defining column widths of four to six feet. Apertures of the columnar joints are typically tight, though two extensively dilated zones have been identified around stations 250+50 and 254+00.

Unit 4: This unit extends the full length along the bottom of the cut and varies in thickness from approximately 70 to 100 feet. The vertical joint set that defines the columnar structure has typically medium to high persistence and moderate spacing defining column widths of two to three feet. Apertures of the columnar joints are typically tight to less than one inch.

Evident throughout the rock slope in all units are closely to extremely widely spaced joints of low to high persistence with typical tight to open apertures. These joints characteristically have a moderate inclination that dips west, out of the slope, towards the highway. The large midslope bench is defined by this joint set. Unlike the vertical joint set defining the columnar structure that resulted from cooling of the basalt lavas, this adversely oriented joint set is believed to be tectonic in origin related to regional folding and faulting (Figured 4).

Rock Fall Occurrence

The rock slope sits within the Columbia River valley approximately 40 feet above the level of the river. At this location the Columbia River valley rises approximately 1000 feet in elevation and is approximately 2.5 miles wide. The rock slope is composed of a nearly vertical basalt cliff that rises from the highway approximately 300 feet to a large talus slope above. The talus slope has recently been stabilized near the crest of the lower cliff face with a 30-foot-high soil nail wall. Above the soil nail wall, the talus slope is inclined at approximately 27 degrees for an approximate 400 foot vertical elevation change before a final 300 foot vertical cliff to the top of the valley. To mitigate the rock fall hazard, the slope protection will cover the lower 300 ft high bedrock slope from the soil nail wall down to the highway over an approximate horizontal distance of 650 feet.

At station 250+50 the rock slope is inclined at approximately 75 degrees above a small talus slope. It contains a few large detached basalt columns with their top heights approximately 200 feet above the highway. At station 252+90, the rock slope rises almost vertically for approximately 130 feet before it reaches an inclined bench at nearly 45 degrees. The bench extends eastward for approximately 80 feet. Above the bench a large overhang exists that extends back into the slope for approximately 20 feet. Basalt blocks with an average diameter of 3 ft compose the roof of the overhang. Above the overhang the rock slope rises approximately 100 feet to the crest of the slope. This upper area contains numerous detached blocks, some of which are up to 6 ft in diameter. At station 254+00, the rock slope rises almost vertically for approximately 130 feet to the southern most portion of the inclined bench. Above the bench there are a couple of large detached basalt columns with their top heights approximately 200 feet above the highway. Above the basalt columns the rock slope rises almost vertically for approximately 100 feet to the crest of the slope.

Rock fall is a frequent occurrence on this slope. Maintenance reports that from within the project limits they have experienced 3 to 4 rock fall events per year involving blocks of 1 to 2 ft in diameter that reach the shoulder or the travel lanes, with more frequent rock falls of smaller sized debris. The source area extends over the entire slope, but most frequently appear to originate from the overhang area along the top of Unit 3 and from Unit 1. On July 4th, 2006, a car was badly damaged by falling rock originating from the vertical rock slope and minor injuries occurred. On July 6, 2007 a site visit revealed that the rock fall event originated near the crest of a locally overhung section of the cliff (Unit 3). At that time, widely opened fractures that bound blocks or other indicators of slope distress were not observed.

Site Groundwater

Several test borings near the project site were previously instrumented with piezometers. Periodic water level measurements revealed water levels to be at or below the existing level of the highway. Test boring H-5-99, did not encounter groundwater to a depth of 300 ft below ground surface. During our field reconnaissance water was not observed anywhere on the face of the slope. At the approximate station of 254+00 mineralization was observed on the slope face along the contact of Units 2 and 3, which suggests water seepage during wet periods of the year.

GEOTECHNICAL INVESTIGATION AND ANALYSIS

Field Reconnaissance

Field reconnaissance was conducted to evaluate geologic conditions, to estimate ditch and roadway dimensions, and to evaluate potentially unstable masses on the slope. Photographs were acquired and measurements of geologic structure were made. Additional site visits were conducted to acquire close-up photographs of several unstable blocks on the slope and to obtain design input from experienced contractors on the merits and constructability of several design alternatives.

Photo Interpretation

Photographs were acquired along the top of the slope, the bottom of the slope and from a helicopter. These photographs were used to identify locations of large loose blocks and irregular surfaces along the crest of the slope that would require scaling prior to the covering of the rock slope with slope protection. The photographs that were acquired through the use of a helicopter were used to estimate the size of the unstable blocks and the width of the fractures that were observed behind them. Photographs of the bench area were also used to estimate the surface roughness, which is an input parameter for the Colorado Rock Fall Simulation Program.

Laboratory Testing

Laboratory testing to determine specific gravity was performed on a small rock hand specimen collected from the face of rock cut using AASHTO laboratory testing guidelines. The results were converted to unit weight and used within the Colorado Rock Fall Simulation Program.

Colorado Rock Fall Simulation Program (CRSP)

To minimize the potential for rocks reaching the railroad or the Columbia River during the scaling operations, rock fall simulation software called the Colorado Rock Fall Simulation Program 4.0 (CRSP) was used to develop temporary rock fall protection measures. Roadway design stationing and a digital terrain model provided by the North Central Region were used to develop three critical cross sections at the locations on either end, and directly above, the overhanging section (Figure 4). Table 1 summarizes the rock fall simulation results of three critical cross sections without the deployment of any rock fall protection measures for an analysis point along the south bound edge of pavement. The analysis allows for input of a design block size and shape, and an origin or initiation point, and provides data on the maximum bounce height, velocity, and kinetic energy at a user-specified analysis point (Anal Pt.) and the estimated rollout. Table 2 summarizes results of the same three critical cross sections for an analysis point placed 4 ft from the south bound edge of pavement, with an attenuation blanket covering the roadway and ditch section and a movable rock fall barrier (MRB). This rock fall simulation software was also used for the design of a modified slope protection system along the midslope bench. Table 3 summarizes the simulation results for two of the critical cross sections where the modified slope protection system would be placed. Table 4 summarizes the simulation results for the critical cross section at station 254+00 with the MRB placed 16 ft from the south bound edge of pavement. Plots of the rock fall simulations found in Tables 1 through 4 can be found in Appendix B.

Table 1

Station	Rock Size	Origin (Elev)	Max Bounce	Max Energy	Max Velocity	Passing Analysis Pt.
250+50	6 ft	950 ft – 981 ft	≤ 6 ft	≤ 712,000 ft-lbs	41 ft/sec	70%
250+50	3 ft	950 ft – 981 ft	≤ 6 ft	≤ 114,000 ft-lbs	47 ft/sec	19%
252+90	6 ft	941 ft – 980 ft	≤ 5 ft	≤ 510,000 ft-lbs	35 ft/sec	32%
252+90	3 ft	941 ft – 980 ft	≤ 6 ft	≤ 69,000 ft-lbs	37 ft/sec	9%
254+00	6 ft	860 ft – 950 ft	≤ 13 ft	≤ 2,900,000 ft-lbs	93 ft/sec	100%
254+00	3 ft	860 ft – 950 ft	≤ 8 ft	≤ 361,000 ft-lbs	93 ft/sec	89%

Table 1: Rock fall simulation results without the deployment of any rock fall protection measures at an analysis point along the southbound edge of pavement. The analysis shows that without rock fall protection measures scaled blocks would likely reach the rail lines at all three of the critical cross section locations.

Table 2

Station	Rock Size	Origin (Elev)	Barrier		Energy of Rocks Hitting Barrier	Barrier Height
			Rocks Hit	Rocks Pass		
250+50	6 ft	950 ft – 981 ft	None	None	No rocks	12 ft
250+50	3 ft	950 ft – 981 ft	None	None	No rocks	12 ft
252+90	6 ft	941 ft – 980 ft	None	None	No rocks	12 ft
252+90	3 ft	941 ft – 980 ft	None	None	No rocks	12 ft
254+00	6 ft	825 ft – 860 ft	54 %	None	≤ 265,000 ft-lbs	12 ft
254+00	3 ft	825 ft – 860 ft	18 %	None	≤ 34,000 ft-lbs	12 ft

Table 2: Rock fall simulation results with a minimum 18 inch attenuation blanket on the roadway and ditch section with a movable rock fall barrier placed 4 feet from the southbound edge of pavement.

Block sizes smaller than 6 ft and larger than 3 ft were also modeled and their kinetic energies, rollout distances, bounce heights, and velocities are between the values shown in Tables 1 and 2. Based upon the rock sizes observed in the ditch and the observed rockmass conditions, we anticipate that the larger blocks will break apart into block sizes less than 4 ft in diameter as they travel down the slope. Table 3 summarizes the bounce heights, velocities, and the kinetic energies of rocks that would impact a modified slope protection system designed for the bench area directly below the overhang area (stations 252+90 & 254+00). For this analysis we considered block sizes ranging from 3 to 6 ft. We anticipate that 3 to 4 ft. blocks would be most typical.

Table 3

Station	Rock Size	Origin (Elev)	Bounce	Kinetic Energy	Max Velocity
252+90	6 ft	850 ft – 855 ft	≤ 4 ft	≤ 759,000 ft-lbs	46 ft/sec
252+90	3 ft	850 ft – 855 ft	≤ 5 ft	≤ 93,000 ft-lbs	46 ft/sec
254+00	6 ft	820 ft – 825 ft	≤ 4 ft	≤ 760,000 ft-lbs	46 ft/sec
254+00	3 ft	820 ft – 825 ft	≤ 6 ft	≤ 91,000 ft-lbs	46 ft/sec

Table 3: Estimated maximum bounce heights, kinetic energies and velocities for blocks that would impact a modified slope protection system along the edge of the midslope bench.

Table 4 summarizes the rock fall simulation results of a critical cross section at station 254+00, scaling Area C. This simulation used an analysis point 16 ft inside the south bound edge of pavement with an attenuation blanket covering the roadway and ditch section, and a movable rock fall barrier placed 16 ft inside the southbound edge of pavement. The results indicate that the kinetic energies of the rocks impacting the MRB are beyond its capacity of 160,000 ft-lbs.

Table 4

Station	Rock Size	Origin (Elev)	Barrier		Energy of Rocks Hitting Barrier	Barrier Height
			Rocks Hit	Rocks Pass		
254+00	6 ft	825 ft – 860 ft	90 %	< 1 %	≤ 2,700,000 ft-lbs	12 ft
254+00	3 ft	825 ft – 860 ft	51 %	< 1 %	≤ 326,000 ft-lbs	12 ft

Table 4: Rock fall simulation results with a minimum 18 inch attenuation blanket on the roadway and ditch section with a movable rock fall barrier placed 16 ft inside the southbound edge of pavement.

Table 5 summarizes the rock fall simulation results of a critical cross section at station 254+00 with a minimum 18 inch attenuation blanket placed within the ditch section and the traveled lanes and a 9 ft ecology block wall/earthen berm built 12 ft from the south bound edge of pavement. The CRSP analysis shows that the scaled rocks will have kinetic energies between 347,000 ft-lbs and 2,870,000 ft-lbs and that 81% to 99% of the scaled rocks will hit the front of the berm (approximately 24 ft from the south bound edge of pavement) but less than 1% of the rocks will pass the berm. It should be noted that the design capacity of the ecology block wall/earthen berm has not been determined.

Table 5

Station	Rock Size	Origin (Elev)	Berm		Energy of Rocks Hitting Berm	Berm Height
			Rocks Hit	Rocks Pass		
254+00	6 ft	825 ft – 860 ft	99 %	<1 %	≤ 2,870,000 ft-lbs	9 ft
254+00	3 ft	825 ft – 860 ft	81 %	<1 %	≤ 347,000 ft-lbs	9 ft

Table 5: Rock fall simulation results with a minimum 18 inch attenuation blanket on the roadway and ditch section with an ecology block wall/earthen berm 12 ft inside the southbound edge of pavement.

Rock fall simulation results (Table 2) indicate that at all three critical cross sections (250+50, 252+90, and 254+00), an attenuation blanket with a MRB or an ecology block wall/earthen berm placed along the southbound edge of pavement will retain the scaled rocks. Between stations 250+50 and 252+90, the simulation results indicate the MRB or ecology block wall/earthen berm could be moved towards the rock slope allowing for a 12 ft temporary access road. At cross section 254+00, high risk is associated with moving the MRB or ecology block wall/earthen berm towards the rock slope. At this location, simulation results indicate that the kinetic energies of the scaled rocks will be above the design capacity of the MRB (160,000 ft-lbs) and significant enough to create high risk associated with an untested ecology block wall/earthen berm system.

FINDINGS AND RECOMMENDATIONS

Slope Scaling and Doweling

Three areas of the slope have been identified as requiring hand scaling. These areas have been delineated on Figure 6. To accomplish the hand scaling pry bars, pneumatic pillows, hydraulic jacks, boulder busters or similar tools will be needed. We recommend not allowing the use of expanding grout as a means to break or remove blocks because there are too many uncertainties with its use (i.e. time required to break the rock).

Area A is at the approximate station of 252+50. Several large columns of basalt between elevations 860 and 900 ft have separated from the rock face and need to be removed prior to the placing of the slope protection system (Figure 7). These blocks are estimated to be 30 to 40 feet in height and are approximately 5 feet in diameter. Open fractures behind these blocks have developed and are estimated to be 12 to 18 inches wide. The lower portions of these blocks might be difficult to remove through hand scaling, and rock doweling might be needed to prevent further dilation of these fractures.

Area B is located along the top portion of the slope. Hand scaling is required from the crest of the slope at the approximate elevation of 980 ft, down 30 to 40 feet, to the approximate elevations 940 to 950 ft. A few large unstable blocks have been identified from the helicopter reconnaissance along this section of the slope (Figure 8). Several large blocks of basalt have separated from the rock face and need to be removed prior to the placing of the slope protection system. These blocks have been estimated to be up to 6 feet in diameter and have open fractures up to 12 inches wide. Also within this area, some additional blocks might need to be removed or stabilized through hand scaling or rock doweling.

Area C is located at the approximate station of 254+00, near elevation 825 to 860 feet. Two large columns of basalt have separated from the rock face and need to be removed prior to the placing of the slope protection system (Figure 9). These columns are estimated to be 30 to 40 feet in height and are approximately 5 feet in diameter.

To safely reach areas A and C, additional unstable blocks of various sizes might also need to be removed. We recommend that a total of 140 crew hours be included for hand scaling. The estimated hand scaling crew hours are based upon three crews, of three men each, working simultaneously over a single four-day period. Based on the reviews by the contractors, it is estimated that a maximum of 4 days would be required to complete the hand scaling operations using an uninterrupted full roadway closure. We also recommended that 300 lineal feet of Type 1 Rock Dowels be included within the contract documents (Figure 10). The rock dowels would serve as a contingency item to be used when hand scaling becomes excessively time consuming or too difficult as compared to using these alternative stabilization measures. Determination of the need for rock dowels will be made from inspection by the Geotechnical Division following completion of the scaling. Short duration full roadway closures will be required for the drilling and installation of the rock anchors, if this work cannot be completed during the longer duration scaling closures.

Movable Rock Fall Barrier

To safeguard the rail lines, we recommend that our movable rockfall barrier (MRB) be placed below all areas where hand scaling is to occur (Figures 11 & 12). A twelve-foot-high MRB will be needed to contain rock fall 4 feet from the south bound edge of pavement, between the approximate stations of 250+25 to 254+75. Based on the CRSP analysis, between the approximate stations of 250+25 to 253+50 the MRB could be placed up to 16 ft from the south bound edge of pavement towards the rock slope. At section 254+00, the CRSP analysis shows that the kinetic energies of the rocks hitting the MRB when it is placed 16 ft from the south bound edge of pavement, towards the rock slope, is beyond the MRB's design limits.

As an alternative to the MRB, an ecology block wall with an earthen berm could be constructed in its place. A six-foot-high ecology block wall would be needed between the approximate stations of 250+25 to 253+50 and a nine-foot-ecology block wall would be needed between the approximate stations of 253+50 to 254+50. On the inner side of the wall, facing the rock slope, an earthen berm would need to be constructed to the full height of the ecology block wall. This berm should be constructed on as steep of a slope as possible, no steeper than 1.5H:1V. The berm should be composed of either loosely placed sand or gravel borrow (Figure 13).

Attenuation Blanket

We also recommend that a minimum of 18 inches of earthen material be placed over the ditch section, the traveled lanes, and on top of the removable rock fall barrier base plate to mitigate rock fall roll out as the rock slope is scaled. The attenuation blanket should be placed below all the areas where hand scaling is to occur. Ideally, the material should consist of loosely placed sand.

Additional Areas for Protection

As a final precaution to protect the railroad, we recommend that the railroad be covered with ballast below all the areas where the hand scaling is to occur (approximate stations 250+25 to 254+50). The sensitive "switch control box" should also be covered with steel plates of the appropriate thickness to protect the box from rock fall. Below the proposed attenuation blanket, steel plates should cover the fiber optic lines that are located within the ditch area directly below the rock slope.

Slope Protection System

After completing the scaling, and potentially the rock dowel installation, the entire slope will be draped with cable net slope protection or modified (post-supported) slope protection between the approximate stations of 250+25 to 256+00. Using the digital terrain model supplied by the Region and GIS, the area of the slope required to be covered by the standard cable net slope protection is approximately 139,000 ft^2, and for a modified system it is approximately 48,000 ft^2 (Figure 14). We recommend applying a 20% contingency on the estimated quantity to account for surface variability and overlap.

We recommend on the north end (approximate station of 250+25 to 252+00) and south end (approximate station of 254+75 to 256+00) of the project that the slope protection system extend down to 5 feet above the base of the rock slope (Figure 15). In the center portion of the project (approximate stations 252+00 to 254+75) the standard slope protection system should cover the overhang and extend approximately 20 feet onto the intermediate mid slope bench. The entire upper portion of the slope would have a standard installation secured by a top horizontal rope and anchors located approximately 15 feet back from the slope crest (Figure 16). A maximum anchor spacing of 20 feet is recommended. The modified slope protection system is to be constructed along the lower edge of the intermediate bench (approximate stations 252+00 to 254+75) and extend down to 5 feet above the base of the rock slope (Figures 17, 18, and 19). The top of the modified slope protection system should be raised 10 feet off the ground, allowing rock fall originating upslope to impact sub-horizontally and then be channeled down to the ditch. The modified slope protection system will be supported by a top horizontal rope suspended between 10 foot high posts anchored to the bench at approximately 20 foot intervals. The two slope protection systems will overlap together on the north and south ends where they meet on the lower sections of the slope.

LIMITATIONS

This report has been prepared to assist the Washington State Department of Transportation in the engineering design and construction of the subject project. It should not be used, in part or in whole, for other purposes without contacting the Geotechnical Division for a review of the applicability of such reuse.

The assessments contained in this report are based on the Geotechnical Division's understanding of the project at the time that the report was written and on site conditions that existed at time of the field investigation. If significant changes in the nature, configuration, or the scope of the project occur during the design process, the Geotechnical Division should be consulted to determine the impact of such changes on the assessments presented in this report.

Questions regarding the contents of this report should be directed to Marc Fish at (360) 709-5498 or Tom Badger at (360) 709-5461.

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APPENDIX A
(Figures)

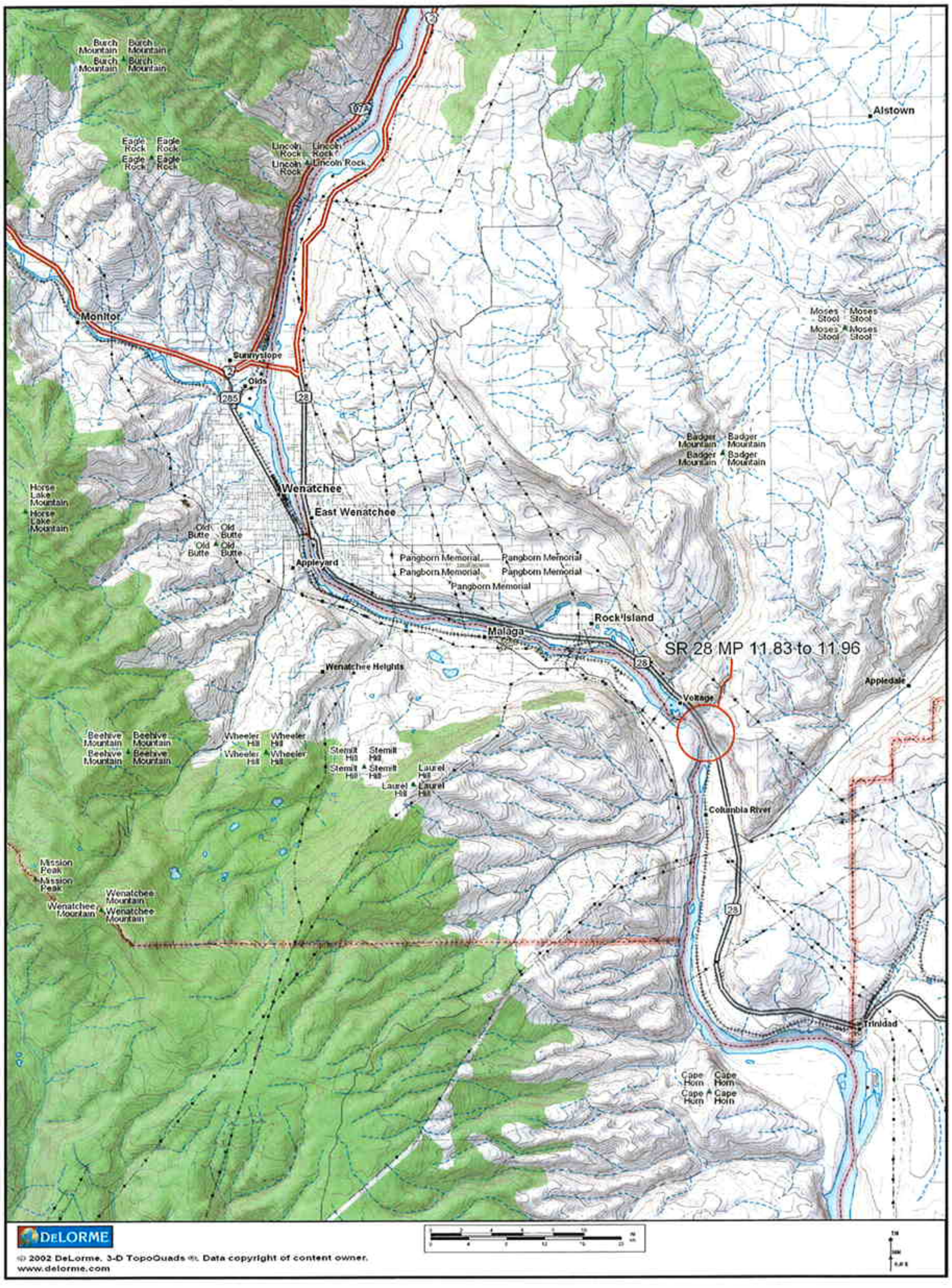

Figure 1: Location Map SR 28 MP 11.83 to 11.96

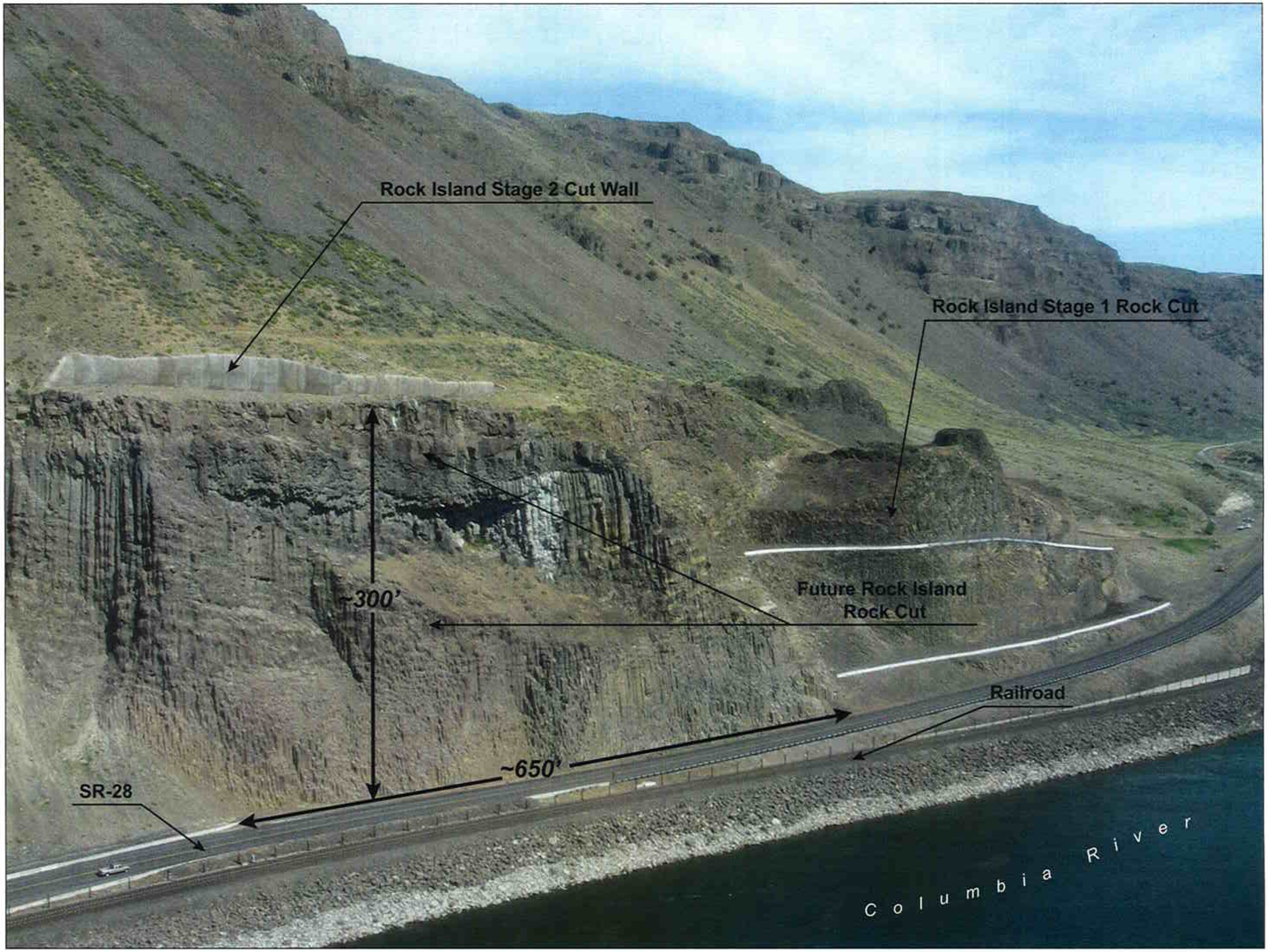

FIGURE 2: A nearly vertical, ~300 foot high basalt cliff that will be mitigated with a drapery system.

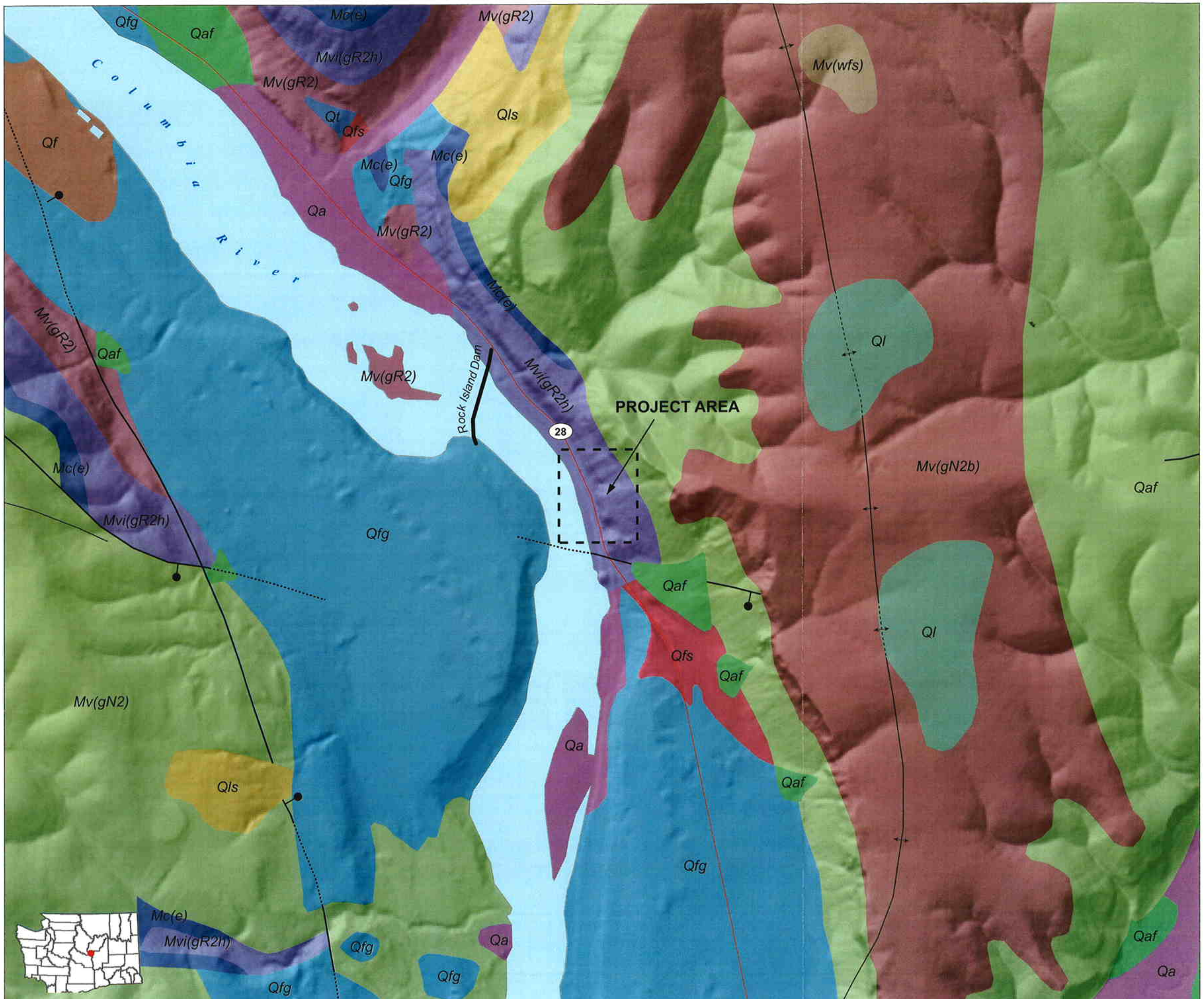

FIGURE 3: LOCAL GEOLOGY

ROCK ISLAND SLOPE STABILIZATION - STAGE 3

SR-28 SRMP 11.91

LEGEND

Geologic Features

Holocene

- Qa — Alluvium
- Qaf — Alluviul Fan Deposits
- Qf — Artifical Fill (including modified land)

Pleistocene

- Qfg — Outburst Flood Deposits, Gravel (Missoula)
- Qfs — Outburst Flood Deposits, Sand & Silt (Missoula)
- Qls — Mass Wasting Deposits (mostly landslides)
- Qt — Terraced Deposits
- Ql — Loess (Palouse Formation)

Middle to Upper Miocene

- Mc(e) — Continental Sedimentary Deposits or Rocks (Ellensburg Formation)

Middle Miocene

- Mv(gR2) — Grande Ronde Basalts (R2)
- Mv(gN2) — Grande Ronde Basalt (N2)
- Mv(wfs) — Frenchman Springs Member (Wanapum Basalt)
- Mv(gN2b) — Grande Ronde Basalt (Beaver Creek)
- Mvi(gR2h) — Grande Ronde Basalt (Hammond Invasive Flow)

Folds

- Anticline
- Anticline - Concealed
- Syncline

Faults

- Normal Fault
- Normal Fault - Concealed
- Downthrown Side of High-angle Faults

- Geologic data provided by: Washington State Department of Natural Resources Division of Geology and Earth Resources Open File Report 2005-3, "Digital 1:100,000-scale Geology of Washington State", version 1.0, December 2005

N

MILES

0 0.125 0.25 0.5 0.75 1

MAP SCALE = 1:7,200

1 INCH = 600'

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION GEOTECHNICAL DIVISION

PROJECT MANAGER	MARC FISH
PROJECT NAME	ROCK ISLAND SLOPE STABILIZATION - STAGE 3
JOB NUMBER	OL-3422
STATE ROUTE	28
MILEPOST(S)	11.91
MAP ID	SR28-OL3422-MF-ROCKISLAND-F3
MAP AUTHOR	ANDY BOHLANDER
DATE	AUGUST 16, 2007

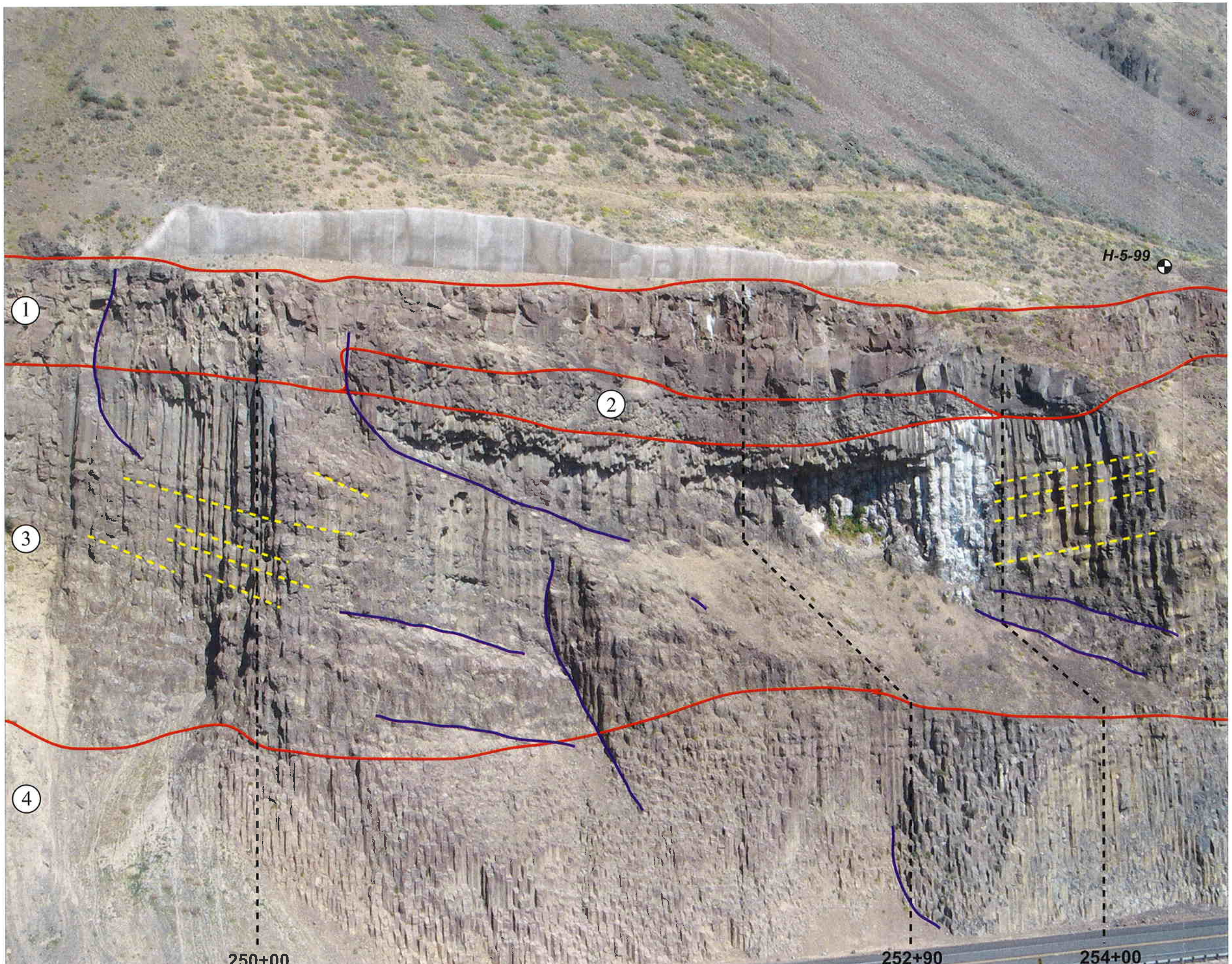

FIGURE 4: ROCK UNITS 1-4, GEOLOGIC STRUCTURE & CRSP CROSS SECTIONS

ROCK ISLAND SLOPE STABILIZATION - STAGE 3

SR-28 SRMP 11.91

LEGEND

Rock Units

Rock Unit Descriptions

1. Columnar structure, blocks up to 6', joints with apparent random orientation
2. Extensively fractured with joints of random orientation
3. Light-dark banding and pervasive columnar jointing with column widths of 4 -6'
4. Columnar structure with column widths of 2 - 3'

Test Boring H-5-99

Approx. Location of CRSP Cross Sections

Discontinuity (Tectonic)

Discontinuity (Banding Cooling Zones)

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION GEOTECHNICAL DIVISION

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MILEPOST(S)	11.91
MAP ID	SR28-OL3422-MF-ROCKISLAND-F5
MAP AUTHOR	ANDY BOHLANDER
DATE	AUGUST 16, 2007

FIGURE 5: Columnar jointing, which dominates much of the slope.

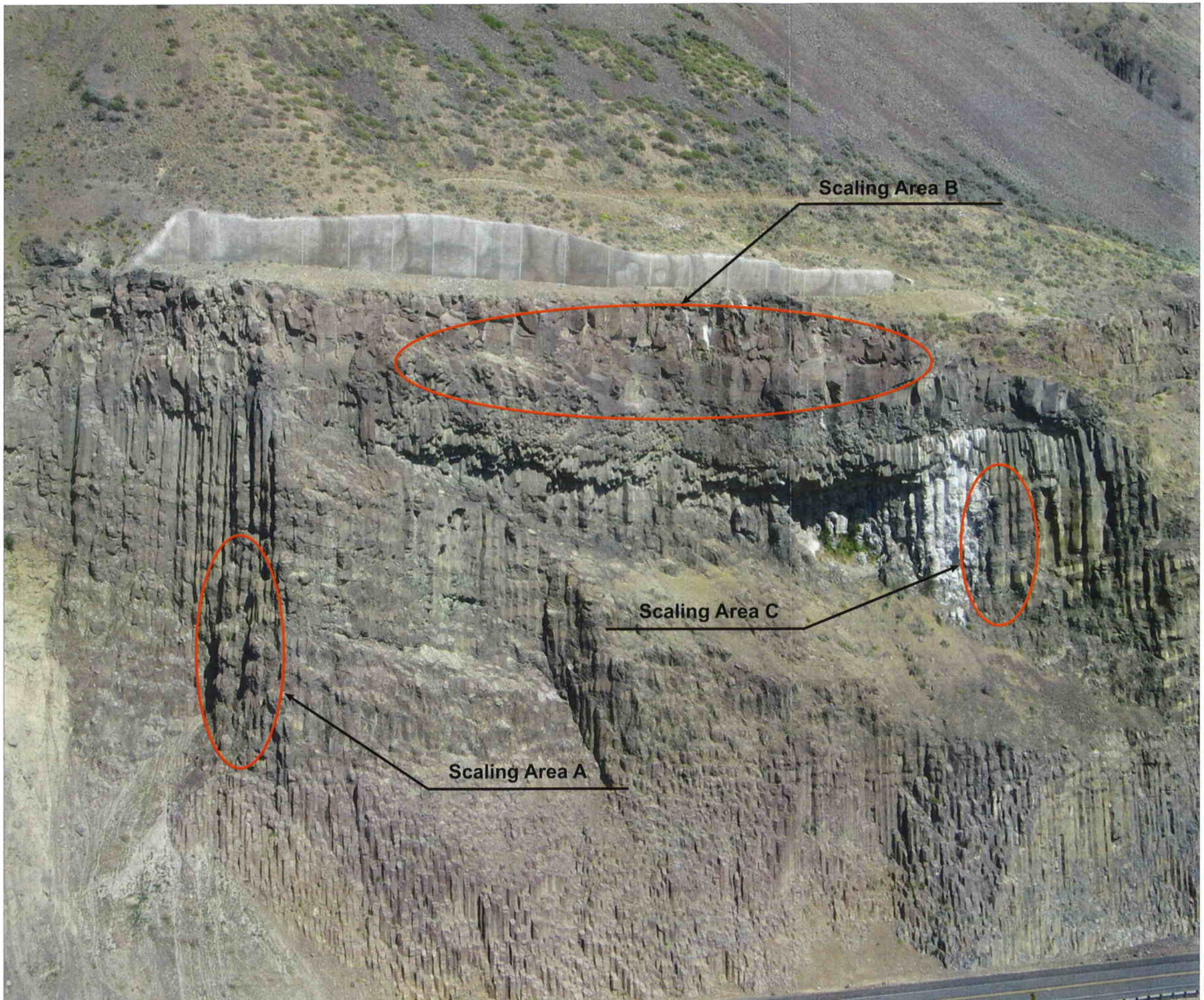


FIGURE 6: SCALING AREAS

ROCK ISLAND SLOPE STABILIZATION - STAGE 3

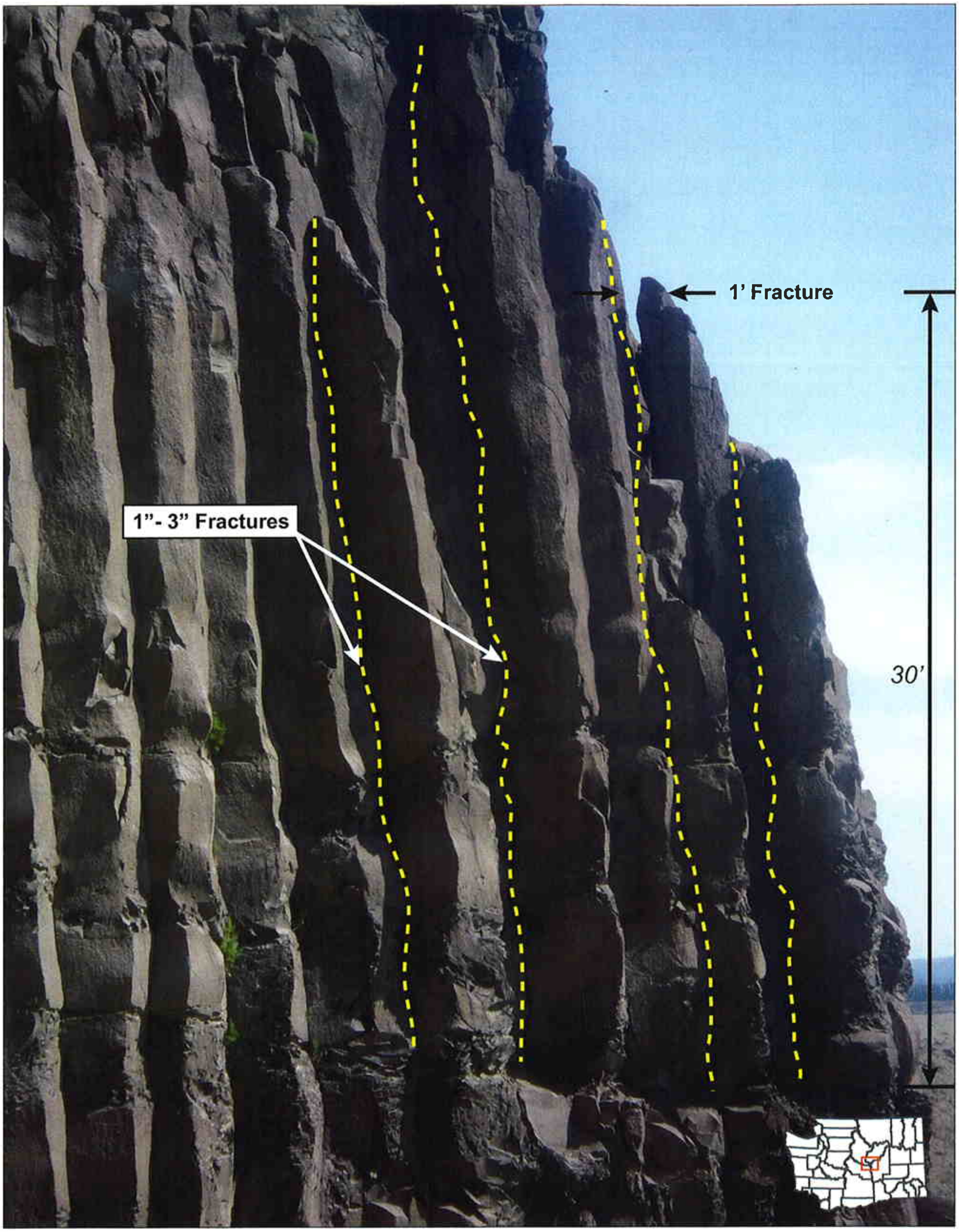
SR-28 SRMP 11.91

LEGEND

Scaling Areas

Washington State Department of Transportation Geotechnical Division

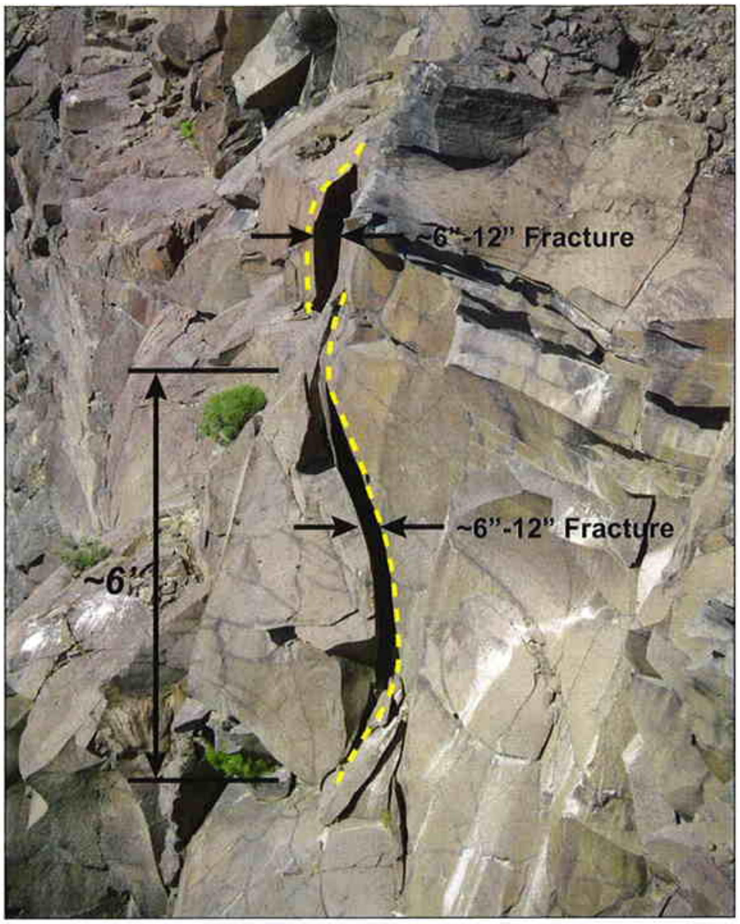
PROJECT MANAGER	MARC FISH
PROJECT NAME	ROCK ISLAND SLOPE STABILIZATION - STAGE 3
JOB NUMBER	OL-3422
STATE ROUTE	28
MILEPOST(S)	11.91
MAP ID	SR28-OL3422-MF-ROCKISLAND-F6
MAP AUTHOR	ANDY BOHLANDER
DATE	AUGUST 24, 2007

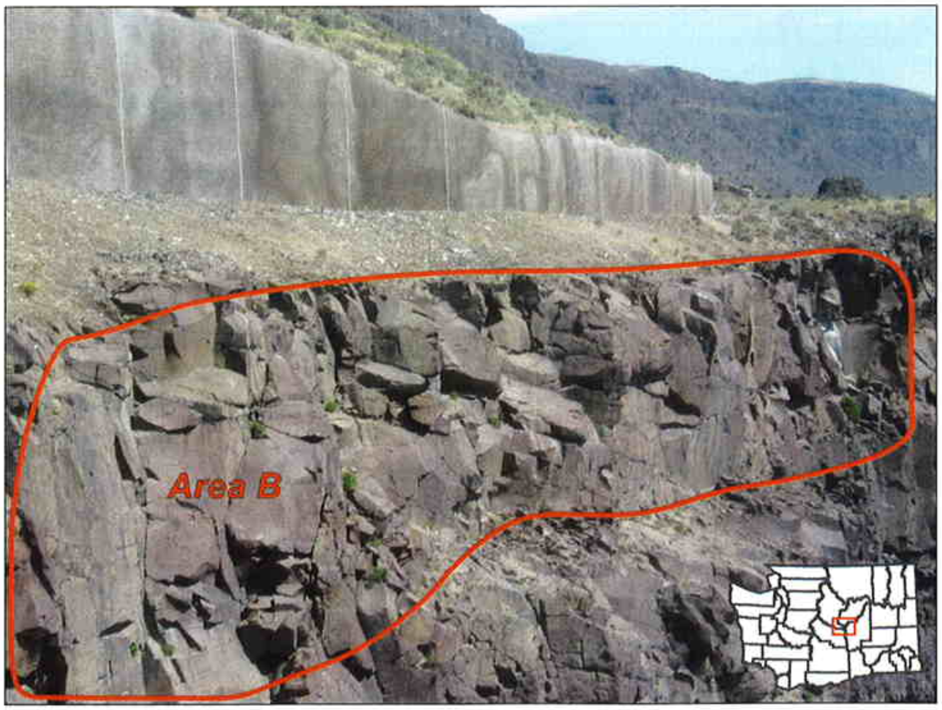


PROJECT MANAGER	MARC FISH
PROJECT NAME	ROCK ISLAND SLOPE STABILIZATION - STAGE 3
JOB NUMBER	OL-3422
STATE ROUTE	28
MILEPOST(S)	11.91
MAP ID	SR28-OL3422-MF-ROCKISLAND-F7
MAP AUTHOR	ANDY BOHLANDER
DATE	AUGUST 24, 2007

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL DIVISION

FIGURE 7: SCALING AREA A
ROCK ISLAND SLOPE STABILIZATION - STAGE 3

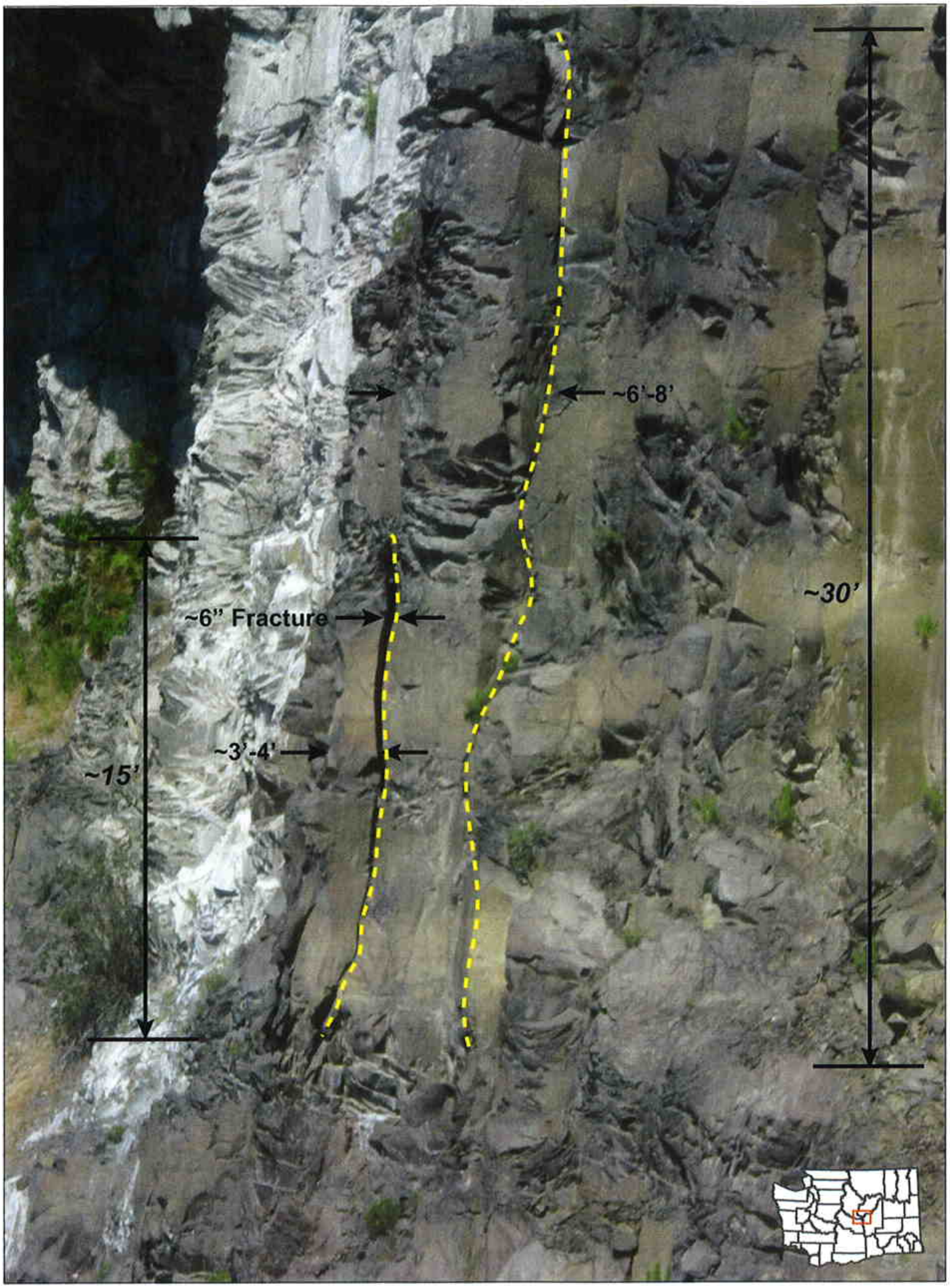




PROJECT MANAGER	MARC FISH
PROJECT NAME	ROCK ISLAND SLOPE STABILIZATION - STAGE 3
JOB NUMBER	OL-3422
STATE ROUTE	28
MILEPOST(S)	11.91
MAP ID	SR28-OL3422-MF-ROCKISLAND-F8
MAP AUTHOR	ANDY BOHLANDER
DATE	AUGUST 24, 2007

FIGURE 8: SCALING AREA B

ROCK ISLAND SLOPE STABILIZATION - STAGE 3



PROJECT MANAGER	MARC FISH
PROJECT NAME	ROCK ISLAND SLOPE STABILIZATION - STAGE 3
JOB NUMBER	OL-3422
STATE ROUTE	28
MILEPOST(S)	11.91
MAP ID	SR28-OL3422-MF-ROCKISLAND-F9
MAP AUTHOR	ANDY BOHLANDER
DATE	AUGUST 24, 2007

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FIGURE 9: SCALING AREA C

ROCK ISLAND SLOPE STABILIZATION - STAGE 3

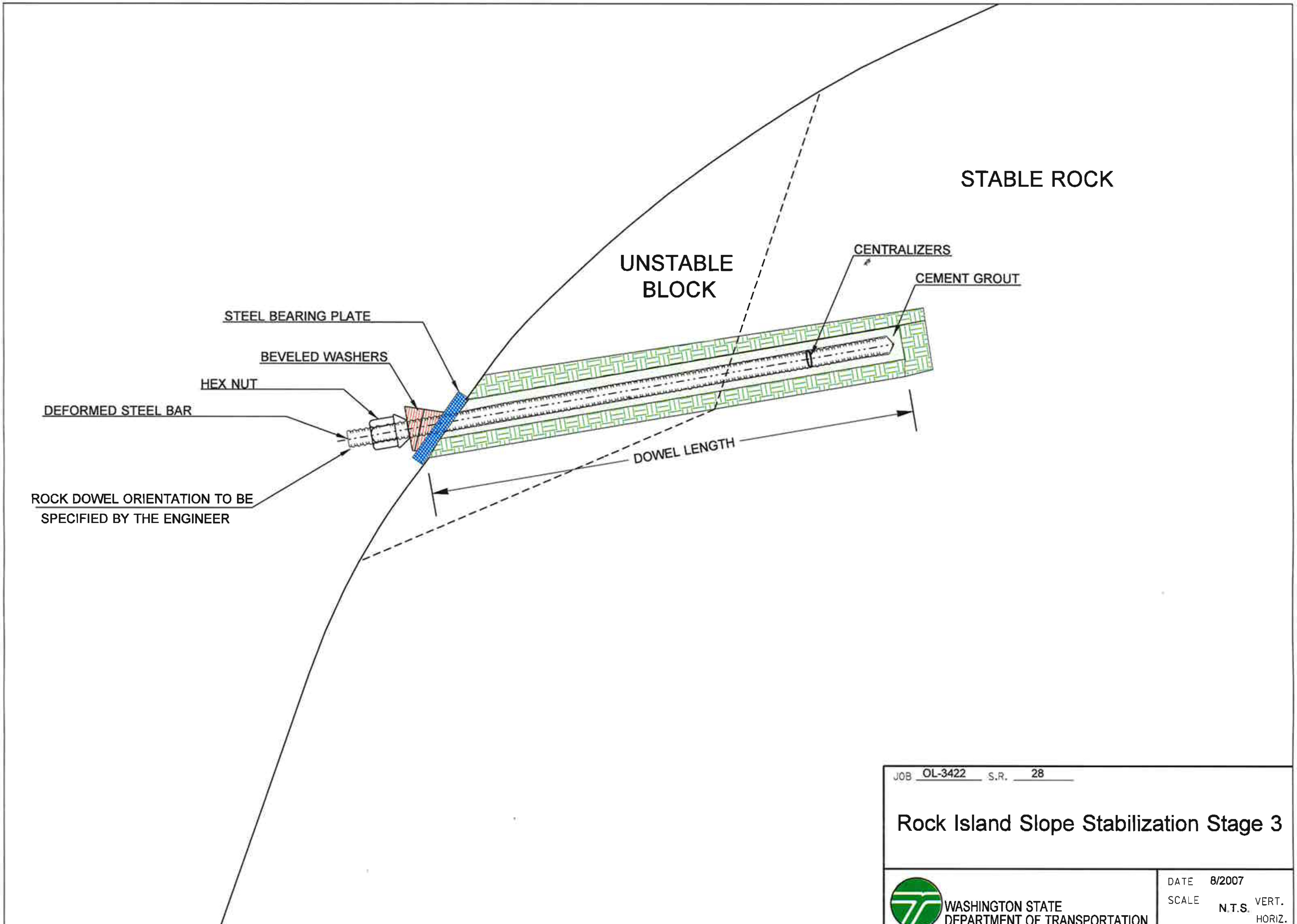
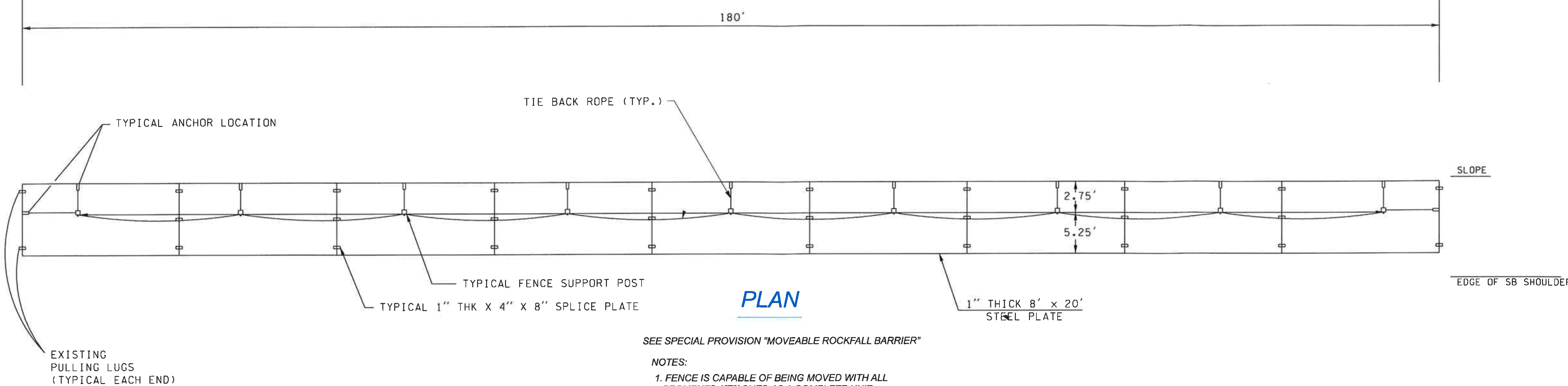


FIGURE 10: TYPICAL TYPE 1 ROCK DOWEL INSTALLATION

JOB OL-3422 S.R. 28		
Rock Island Slope Stabilization Stage 3		
WASHINGTON STATE DEPARTMENT OF TRANSPORTATION GEOTECHNICAL DIVISION	DATE 8/2007 SCALE N.T.S. VERT. HORIZ. SHEET ___ OF ___ DRAWN BY WM	

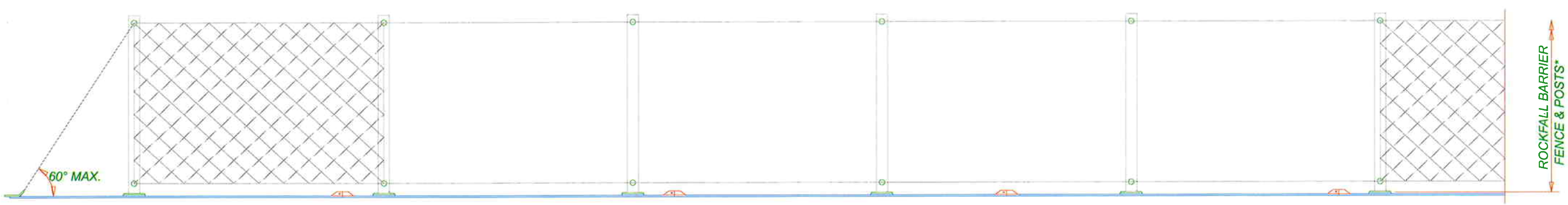


PLAN

SEE SPECIAL PROVISION "MOVEABLE ROCKFALL BARRIER"

NOTES:

1. FENCE IS CAPABLE OF BEING MOVED WITH ALL SEGMENTS ATTACHED AS A COMPLETE UNIT.



ELEVATION

GENERAL NOTES

1. ALL MATERIAL AND WORKMANSHIP SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE WASHINGTON STATE DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS FOR ROAD, BRIDGE AND MUNICIPAL CONSTRUCTION - DATED 2006, AND AMENDMENTS.

2. STRUCTURAL STEEL SHALL MEET THE FOLLOWING MINIMUM REQUIREMENTS:

ANCHOR BOLTS	ASTM F1554 GR 36
PLATES	ASTM A-36

3. HIGH STRENGTH BOLTS SHALL BE ASTM A-325 AND SHALL BE 1"ø. NUTS AND WASHERS SHALL CONFORM TO STANDARD SPECIFICATIONS SECTION 9-06.5(3). BOLT HOLES SHALL BE À" LARGER IN DIAMETER THAN THE BOLT, UNLESS OTHERWISE NOTED IN THE PLANS.

4. WELDING ELECTRODES SHALL BE LOW HYDROGEN AND MEET AWS D1.1 REQUIREMENTS.

5. ANCHORS SHALL BE CUT FLUSH WITH TOP OF ASPHALT SLAB AND SHALL BE COATED WITH EPOXY RESIN. USE TYPE II EPOXY RESIN CONFORMING TO 9.26.1 WITH GRADE AND CLASS REQUIRED BY RESIN MANUFACTURER AND APPROVED BY ENGINEER.

FIGURE 11: MOVEABLE ROCKFALL BARRIER

JOB OL-3422 S.R. 28

Rock Island Slope Stabilization Stage 3

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

GEOTECHNICAL DIVISION

DATE 8/2007

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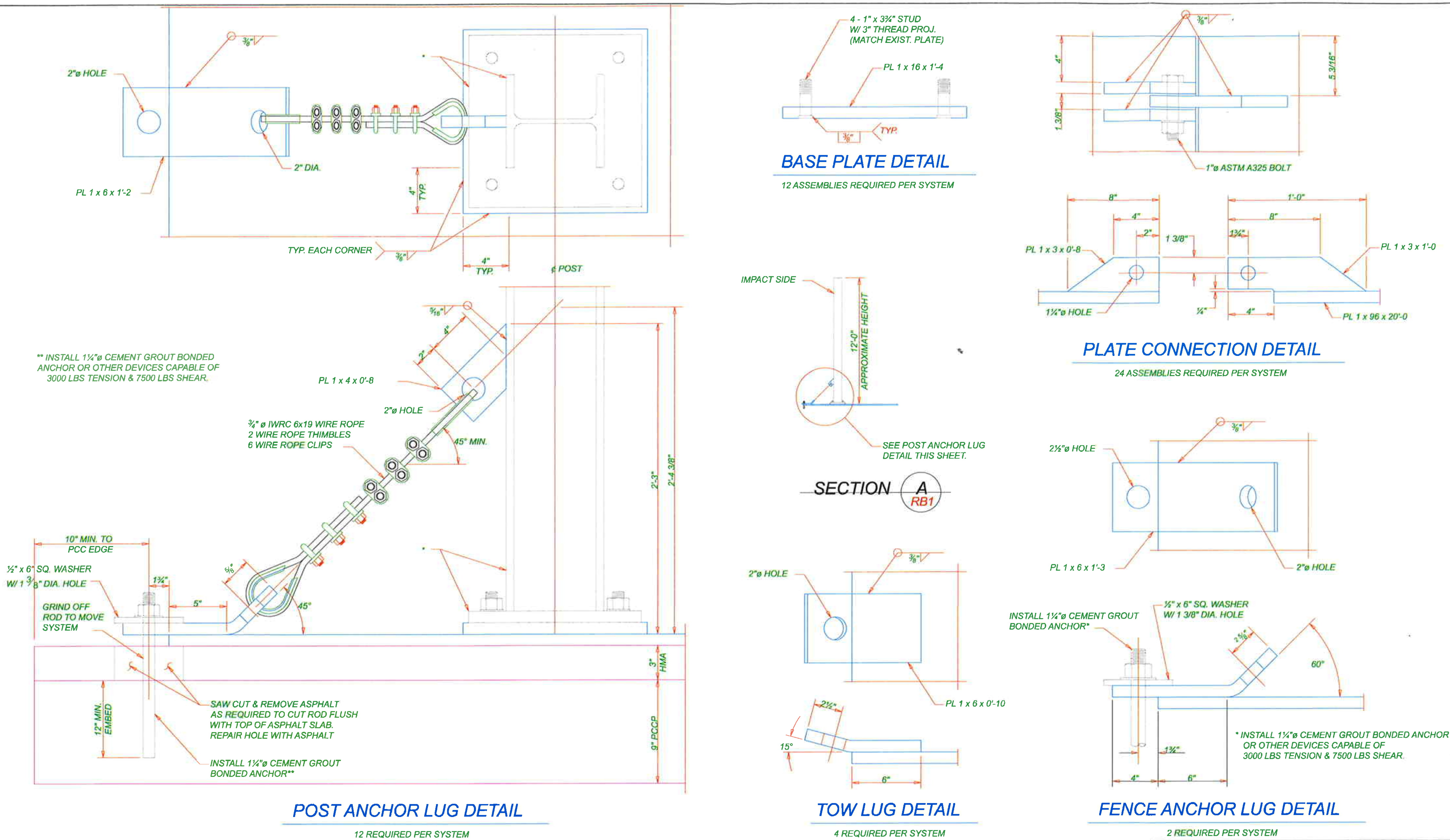
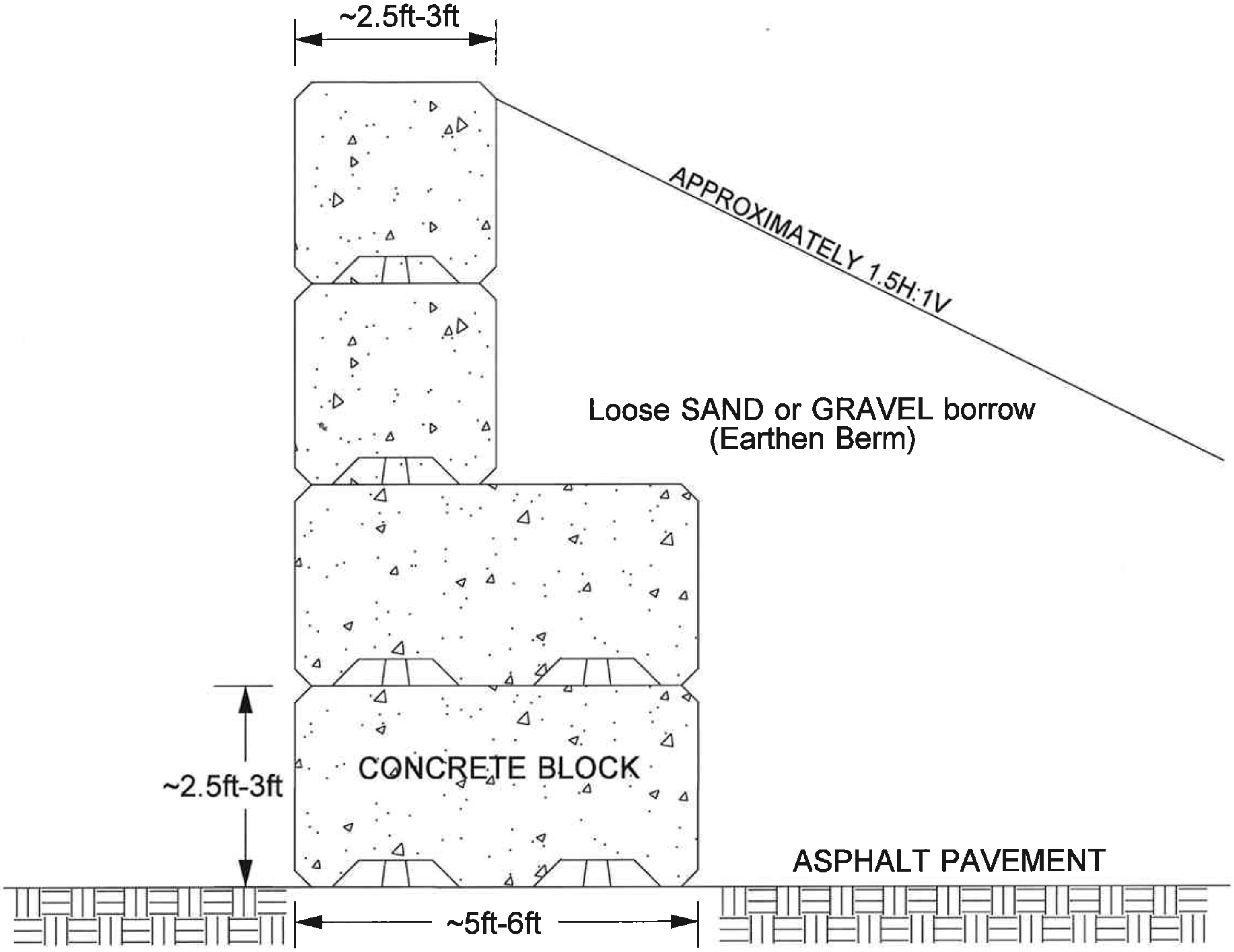


JOB OL-3422 S.R. 28	
Rock Island Slope Stabilization Stage 3	
WASHINGTON STATE DEPARTMENT OF TRANSPORTATION GEOTECHNICAL DIVISION	DATE 8/2007 SCALE N.T.S. VERT. HORIZ. SHEET ____ OF ____ DRAWN BY WM

FIGURE 12: MOVEABLE ROCKFALL BARRIER DETAILS



JOB OL-3422 S.R. 28

Rock Island Slope Stabilization Stage 3

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GEOTECHNICAL DIVISION

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FIGURE 13: ECOLOGY BLOCK WALL/EARTHEN BERM

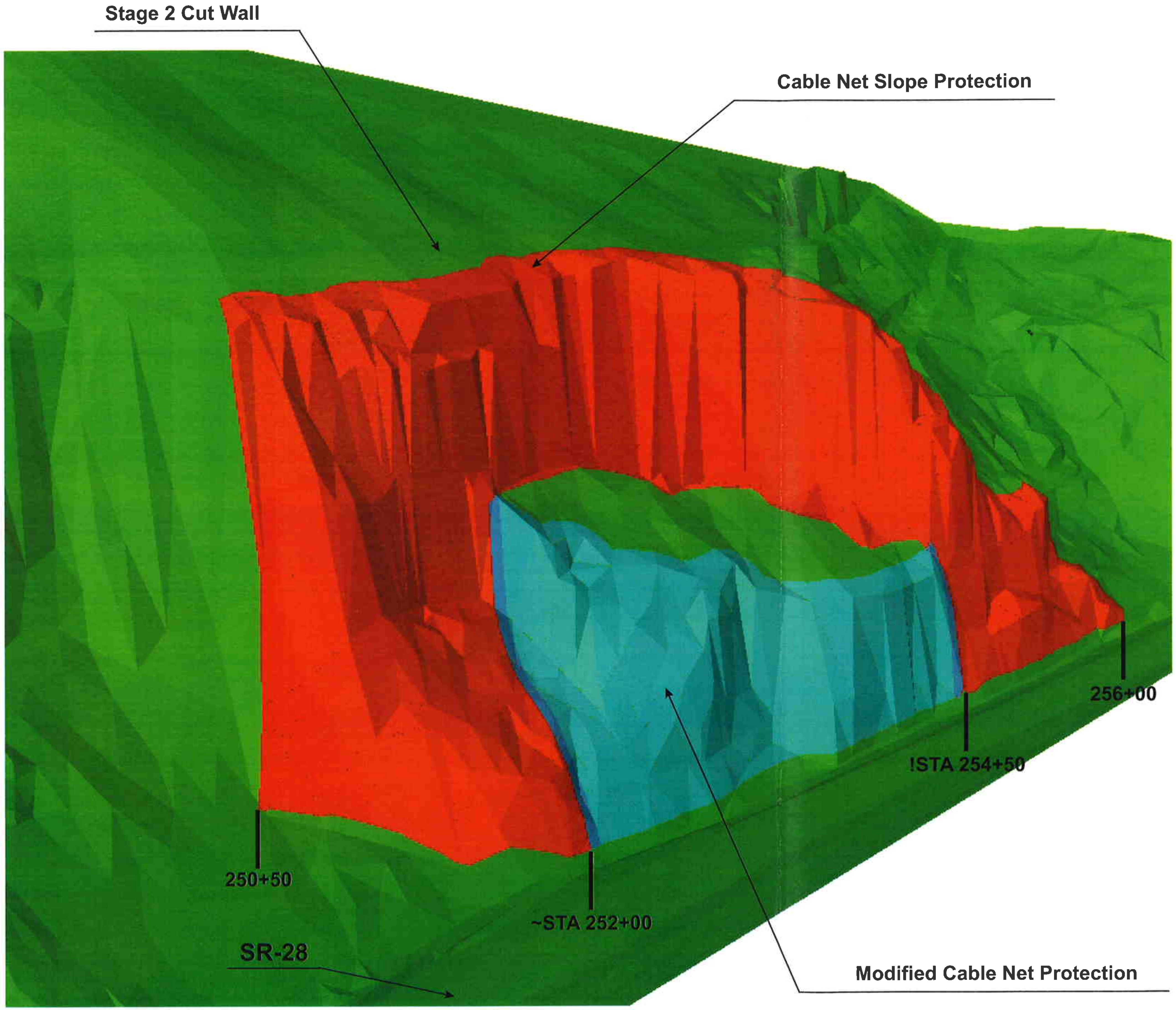

FIGURE 14: SLOPE PROTECTION COVERAGE AREA

ROCK ISLAND SLOPE STABILIZATION - STAGE 3

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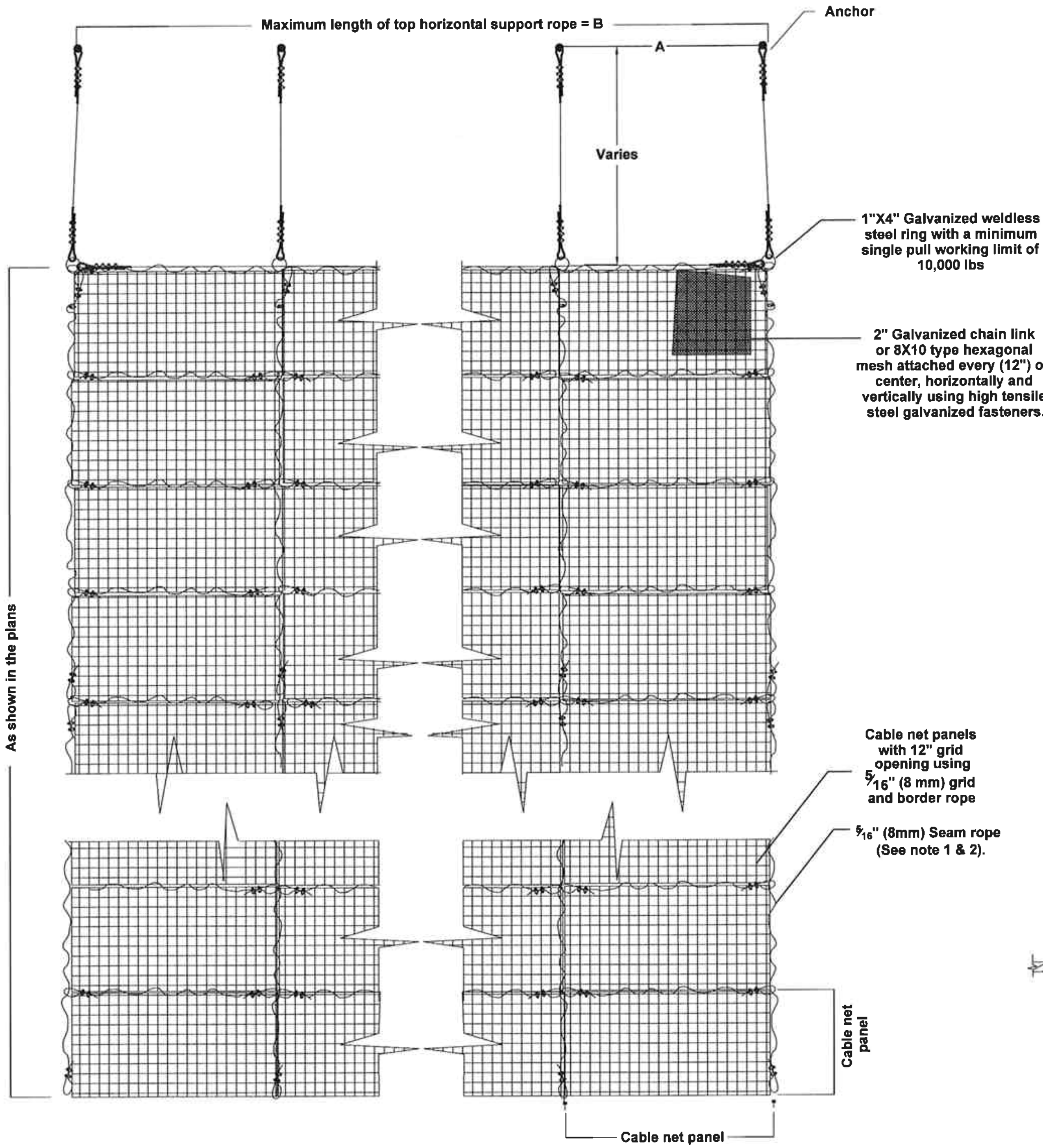
LEGEND

Coverage Area

- 139,000 ft^2
- 48,000 ft^2

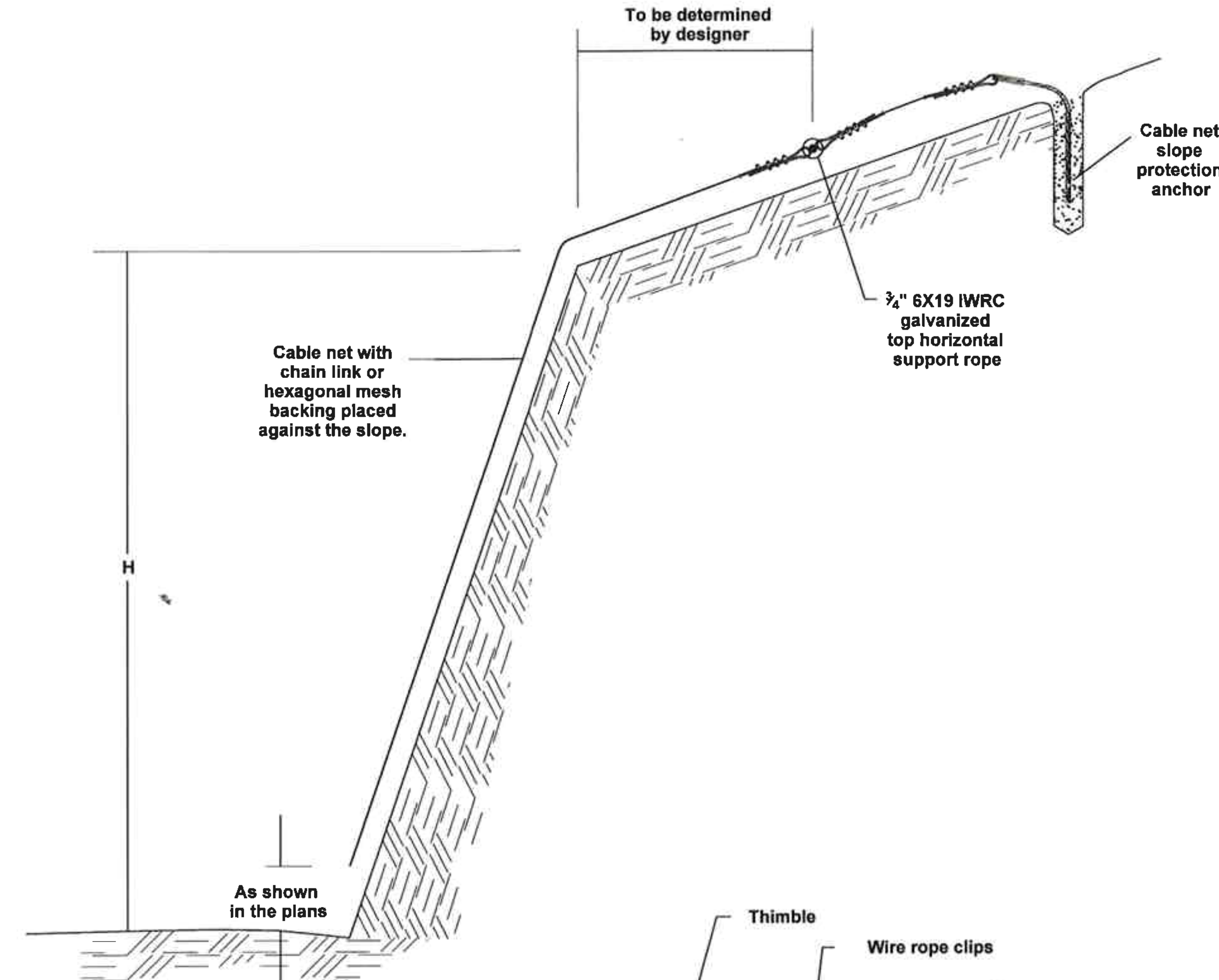
PROJECT MANAGER	MARC FISH
PROJECT NAME	ROCK ISLAND SLOPE STABILIZATION - STAGE 3
JOB NUMBER	OL-3422
STATE ROUTE	28
MILEPOST(S)	11.91
MAP ID	SR28-OL3422-MF-ROCKISLAND-F14
MAP AUTHOR	ANDY BOHLANDER & ERIC BILDERBACK
DATE	AUGUST 28, 2007

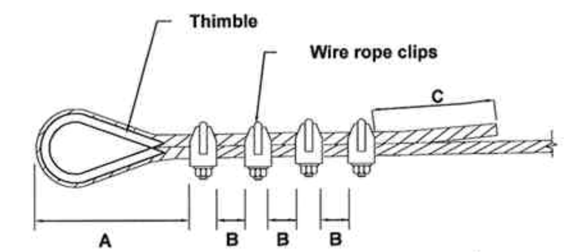


FRONT SLOPE ELEVATION

Maximum Anchor Spacing	
H	A
0-100ft	50ft
100-200ft	35ft
200-300ft	20ft

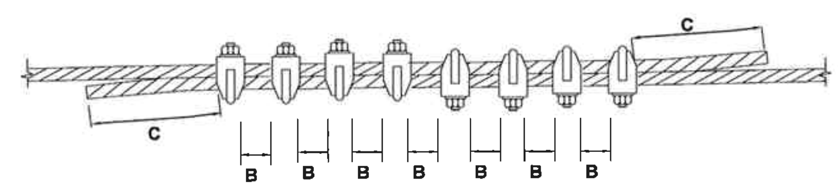
Maximum Length Top Horizontal Support Rope	
H	B
50ft	150ft
100ft	75ft
200ft	40ft
300ft	25ft





WIRE ROPE DETAIL "AA"

Distances A,B,C and torque to comply with manufacturer's specifications



WIRE ROPE DETAIL "BB"

WIRE ROPE SPLICING

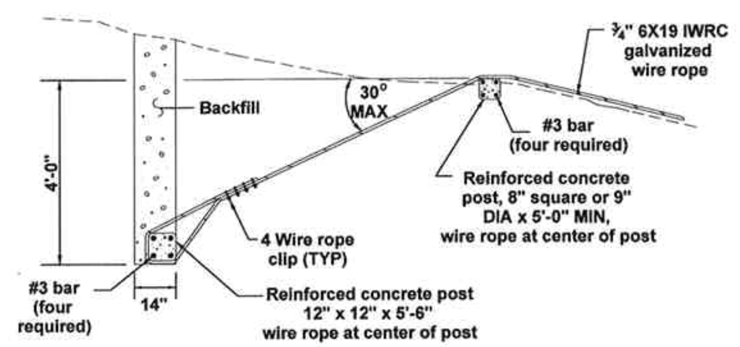
GENERAL NOTES

1. Maximum anchor spacing (A) for debris and impact loads required as per table for a minimum allowable anchor capacity of 20,000 lbs.
2. Cable net panels to be seamed with ◇" wire ropes 5/16" wire ropes through each square of net.
3. Ends of seam ropes are to be terminated with (2)◇" 5/16" wire rope clips.
4. Chain link or hexagonal mesh backing must be fastened to the cable net prior to placement on the slope.

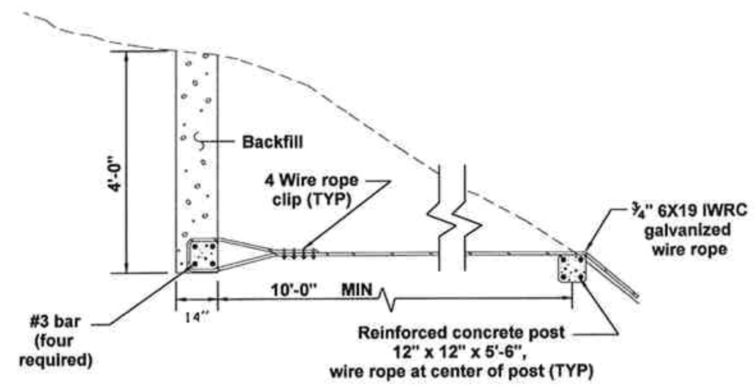
FIGURE 15: CABLE NET SLOPE PROTECTION

JOB OL-3422 S.R. 28	
Rock Island Slope Stabilization Stage 3	
WASHINGTON STATE DEPARTMENT OF TRANSPORTATION GEOTECHNICAL DIVISION	DATE 8/2007 SCALE N.T.S. VERT. HORIZ. SHEET ___ OF ___ DRAWN BY WM

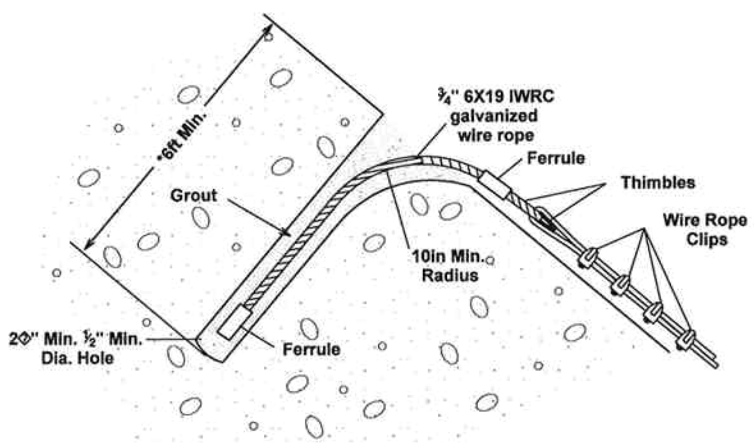
Soil Anchor Details



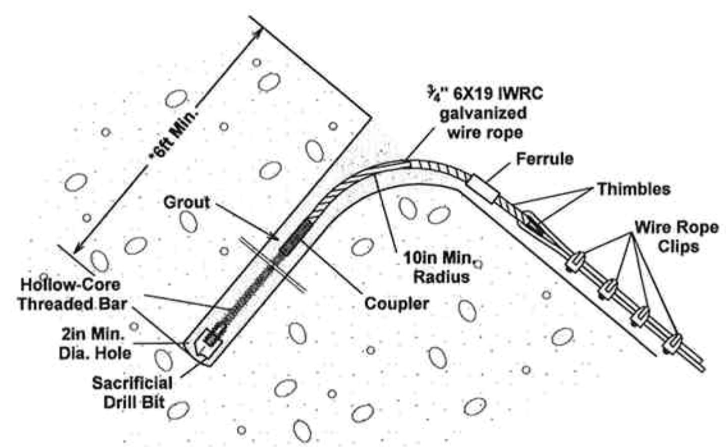
Deadman Type 1
(for use in soil)



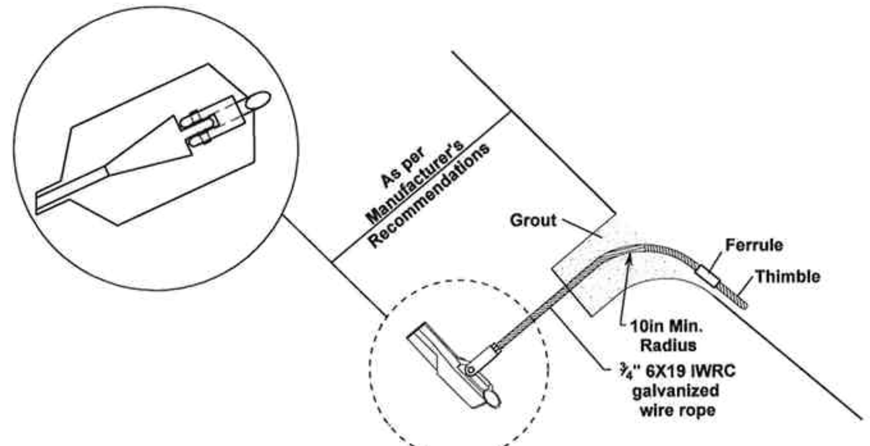
Deadman Type 2
(for use in soil)



¾" Wire Rope
(for use in soil)



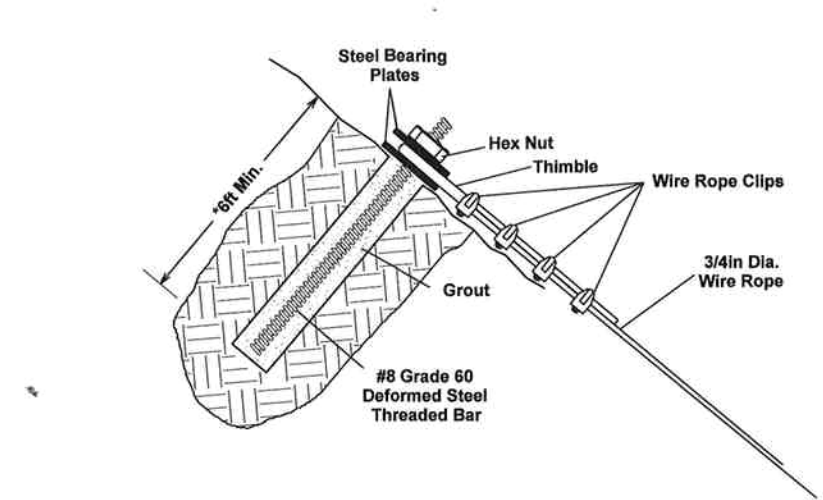
Drillable-Groutable
(for use in soil)



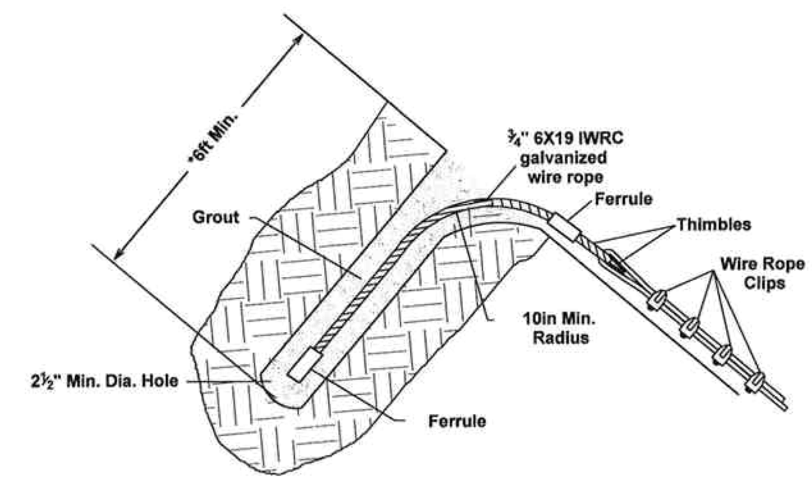
Manta Ray ®
(for use in soil)

*** Suggested minimum depth**

Rock Anchor Details



Deformed Steel Threaded Bar
(for use in rock)



¾" Wire Rope
(for use in rock)

*** Suggested minimum depth**

FIGURE 16: WIRE MESH/CABLE NET ANCHORS

JOB OL-3422 S.R. 28

Rock Island Slope Stabilization Stage 3

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GEOTECHNICAL DIVISION

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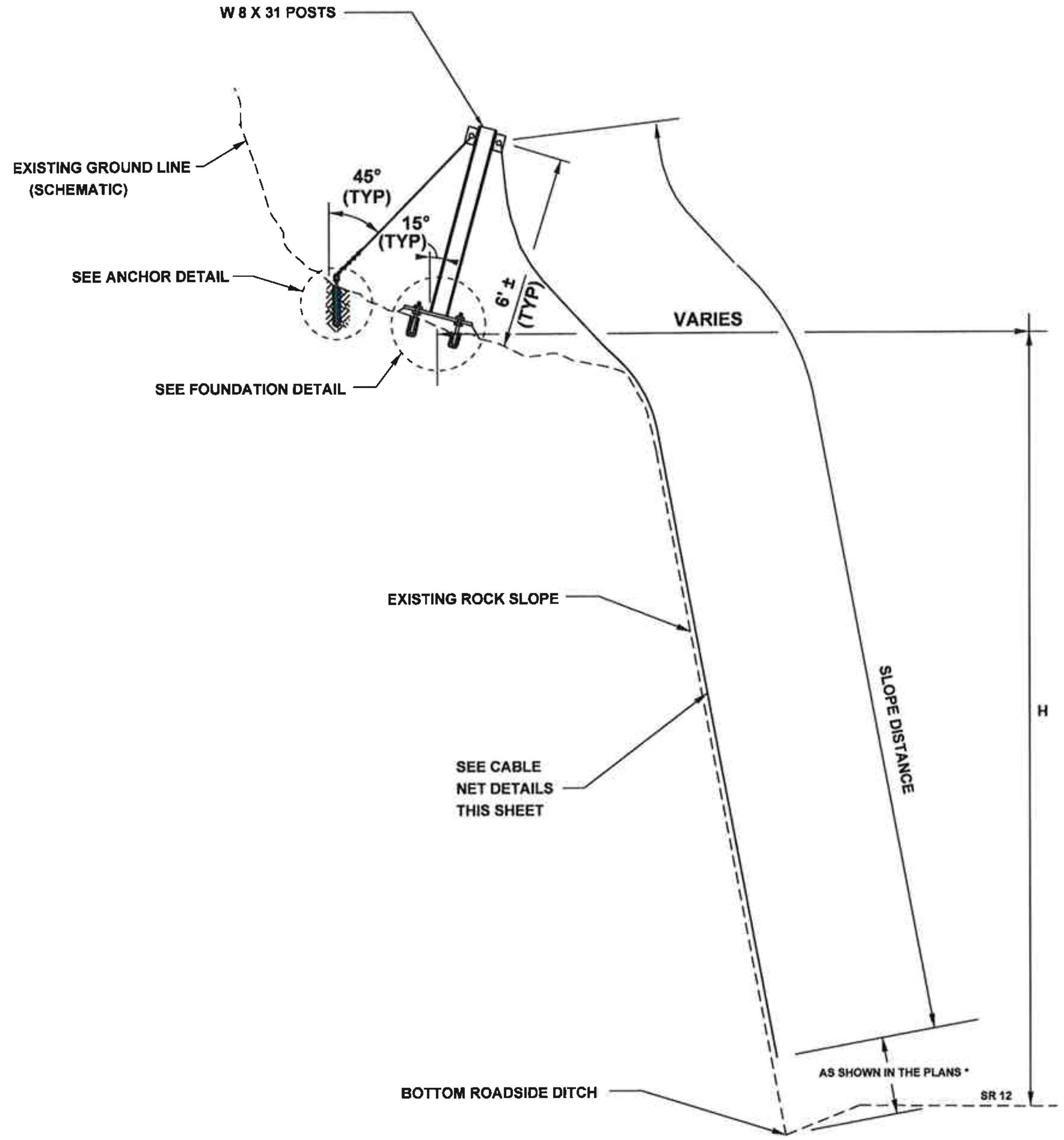

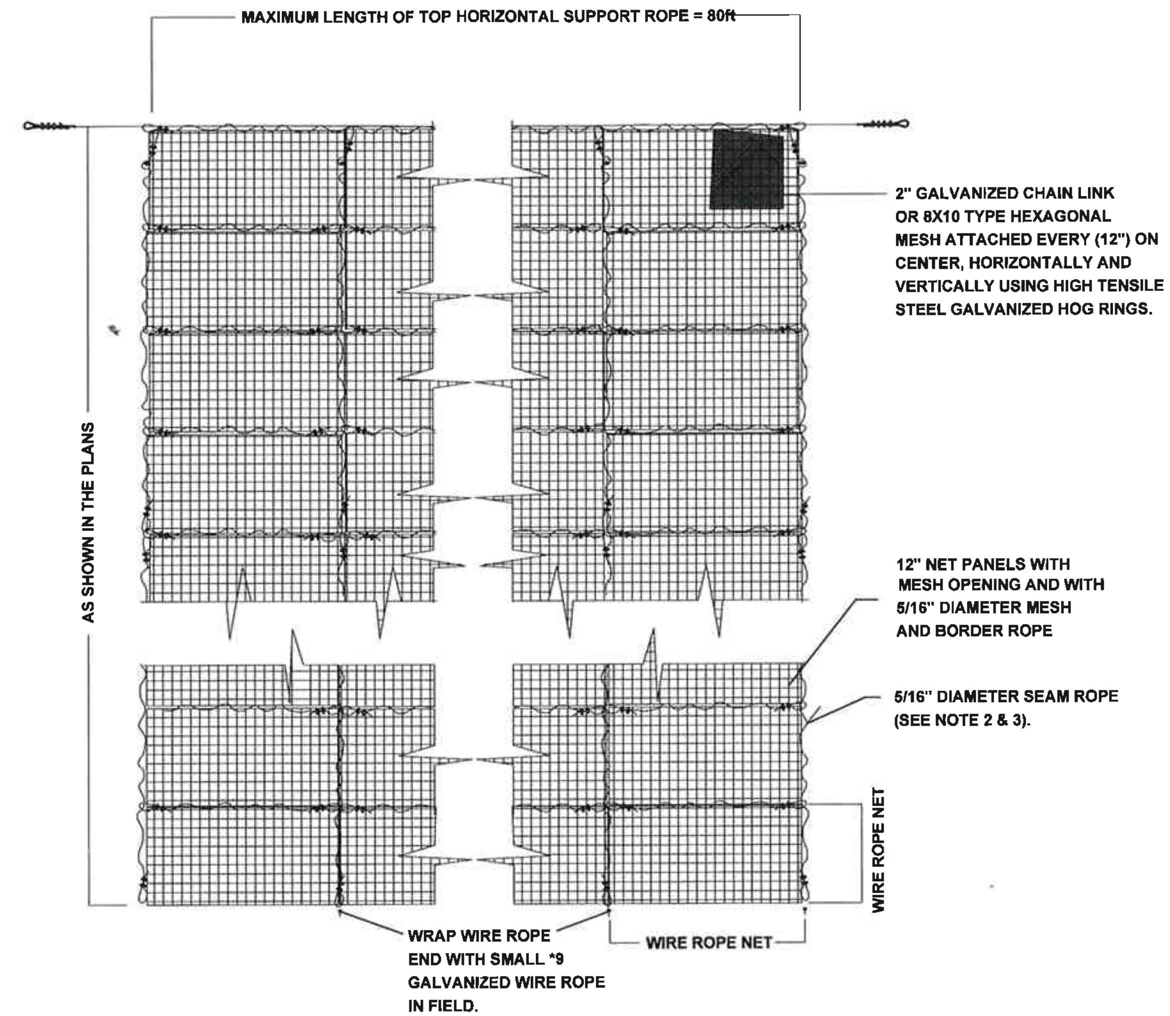

CABLE NET DETAILS

GENERAL NOTES
1. SEE SPECIAL PROVISION "MODIFIED CABLE NET CATCH FENCE".
2. NET TO BE SEAMED WITH 5/16" WIRE ROPES THROUGH EACH SQUARE OF NET.
3. ENDS OF SEAM ROPES ARE TO BE TERMINATED WITH (2) 5/16" WIRE ROPE CLIPS.
4. CHAIN LINK OR HEXAGONAL MESH BACKING MUST BE FASTENED TO THE CABLE NET PRIOR TO PLACEMENT ON THE SLOPE.
5. POSTS SHALL BE SPACED NO MORE THAN 20' APART.

FIGURE 17: MODIFIED CABLE NET SLOPE PROTECTION

JOB OL-3422 S.R. 28

Rock Island Slope Stabilization Stage 3

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

GEOTECHNICAL DIVISION

DATE 8/2007

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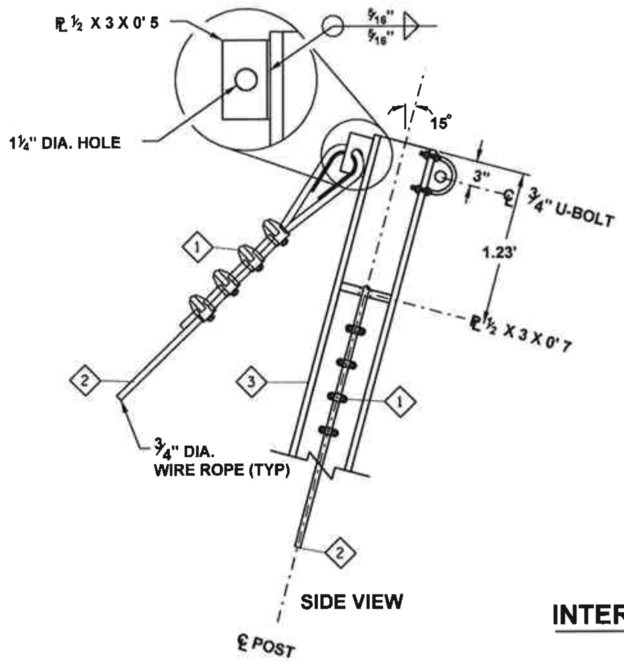
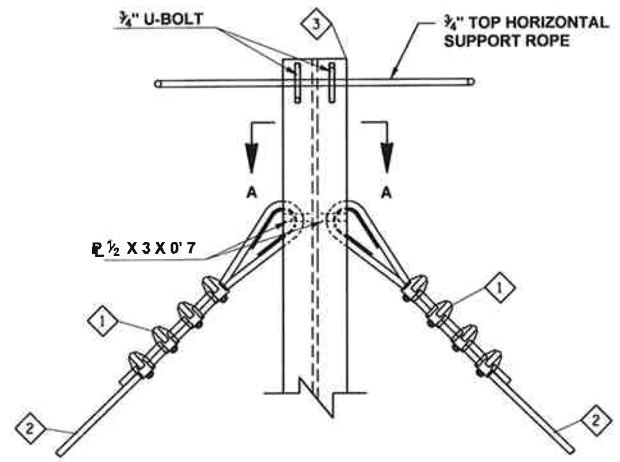
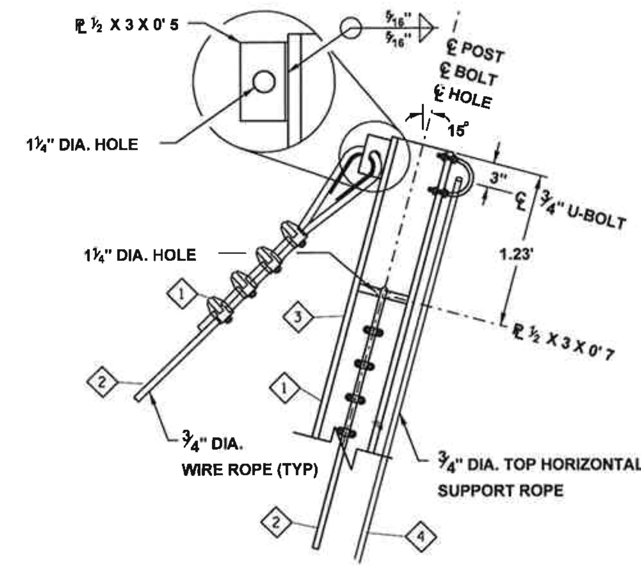


SIDE VIEW

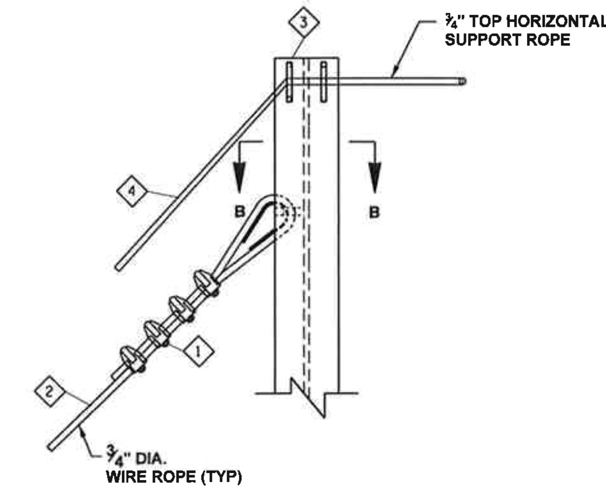


FACE VIEW

INTERMEDIATE POST DETAIL

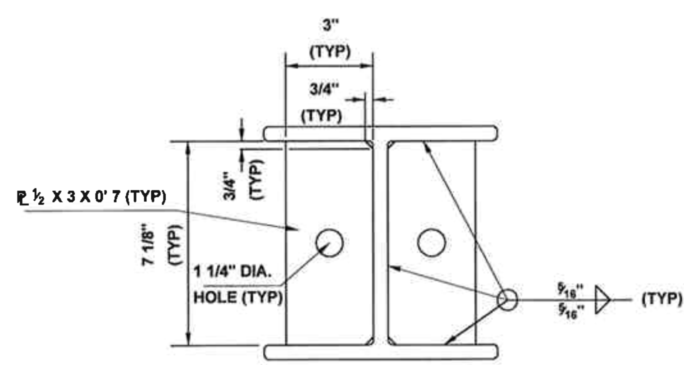


SIDE VIEW

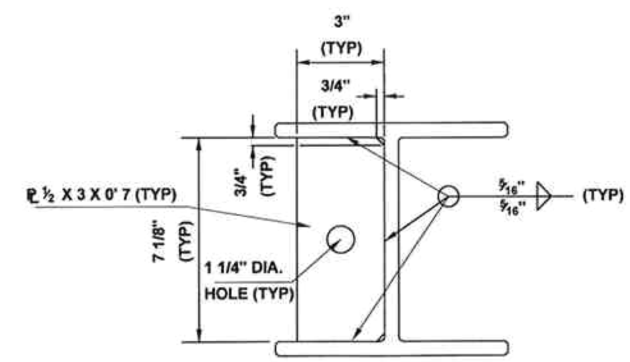


FACE VIEW

END POST DETAIL



SECTION A-A



SECTION B-B

CONSTRUCTION NOTES:

1. SEE WIRE ROPE CONNECTION DETAIL, SHEET DT7
2. SEE ANCHOR CONNECTION DETAIL, SHEET DT7
3. W 8X31 POST
4. SEE HORIZONTAL SUPPORT ROPE ANCHOR DETAIL, SHEET DT7

GENERAL NOTES:

1. SEE SPECIAL PROVISION "MODIFIED CABLE NET SLOPE PROTECTION".

FIGURE 18: MODIFIED CABLE NET SLOPE PROTECTION - POST DETAILS

JOB OL-3422 S.R. 28

Rock Island Slope Stabilization Stage 3

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GEOTECHNICAL DIVISION

DATE 8/2007
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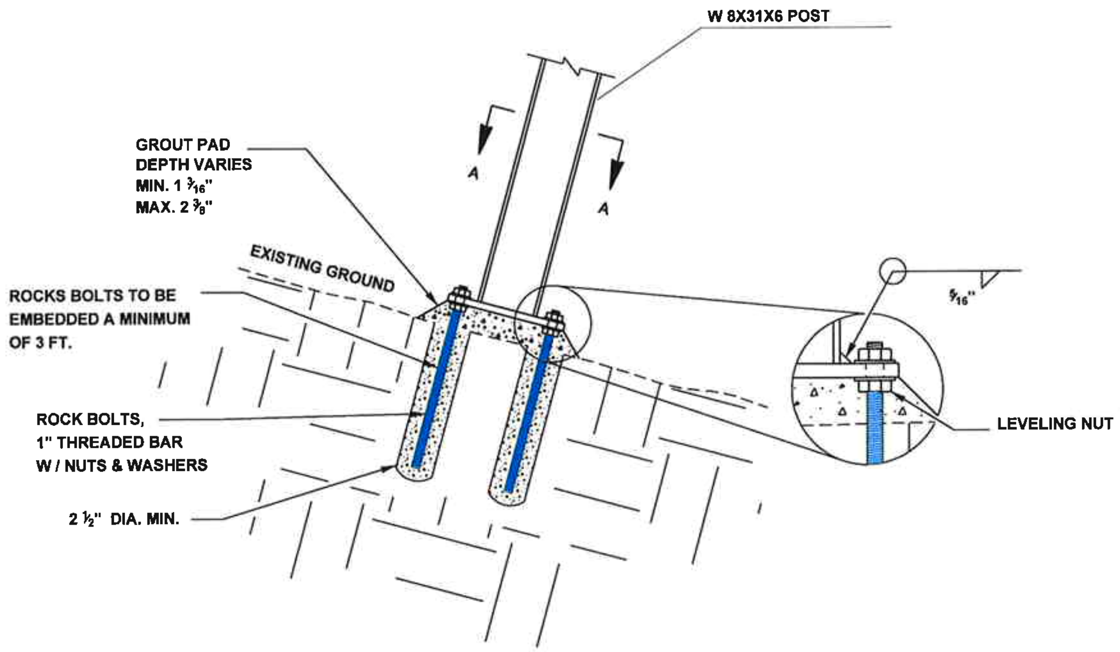
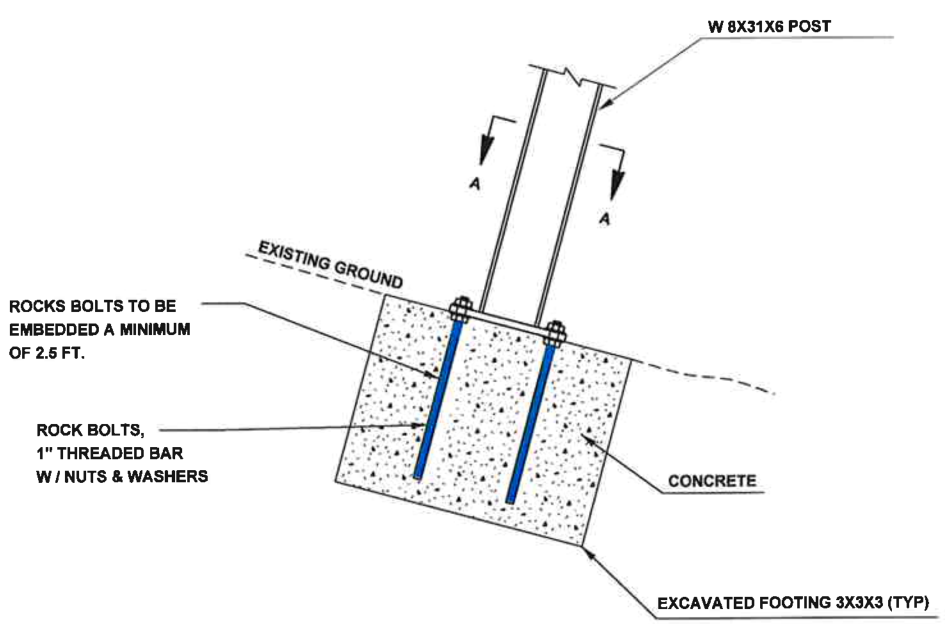
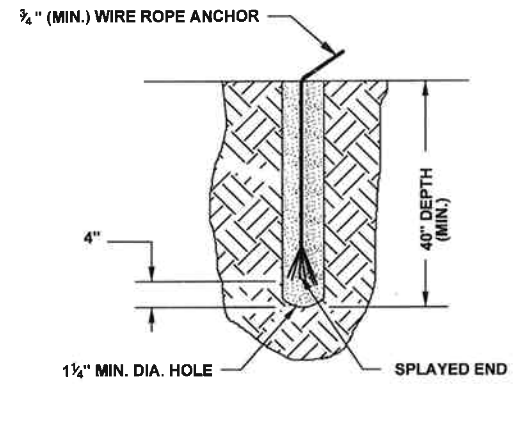


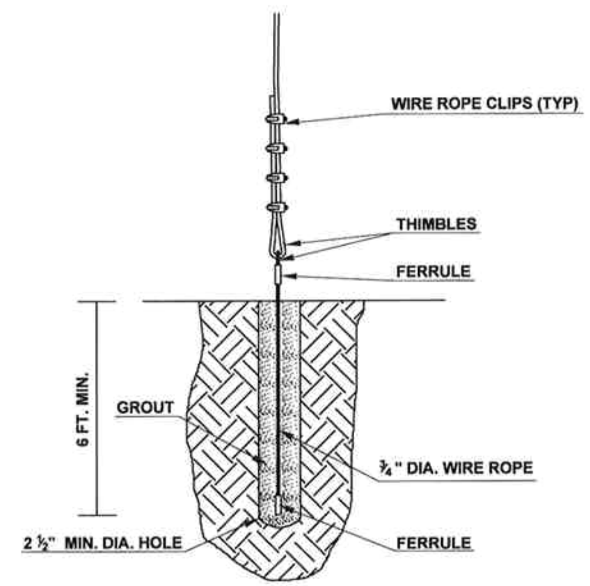
ROCK FOUNDATION DETAIL



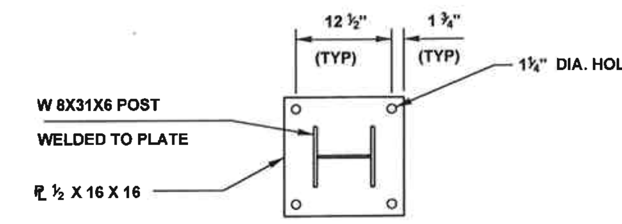
SOIL FOUNDATION DETAIL



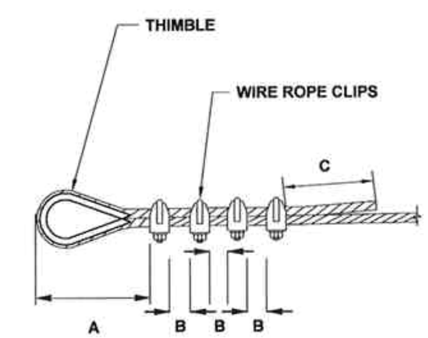
ANCHOR DETAILS



3/4" DIA. WIRE ROPE
(FOR USE IN SOIL OR ROCK)



SECTION A-A



WIRE ROPE CONNECTION DETAIL
AS PER MANUFACTURER'S SPECIFICATIONS

GENERAL NOTES:
1. SEE SPECIAL PROVISION "MODIFIED CABLE NET CATCH FENCE".

JOB OL-3422 S.R. 28

Rock Island Slope Stabilization Stage 3

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DEPARTMENT OF TRANSPORTATION

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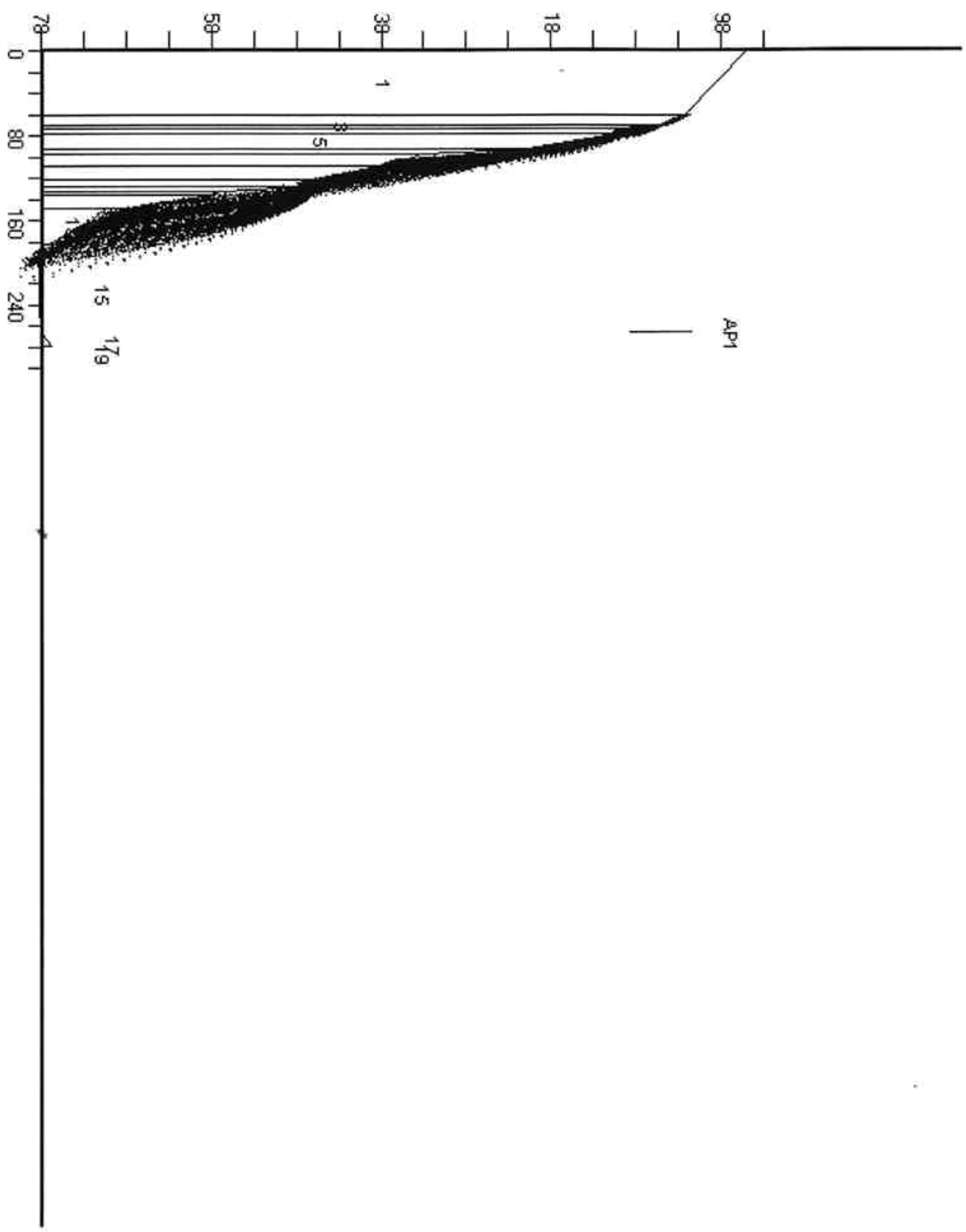
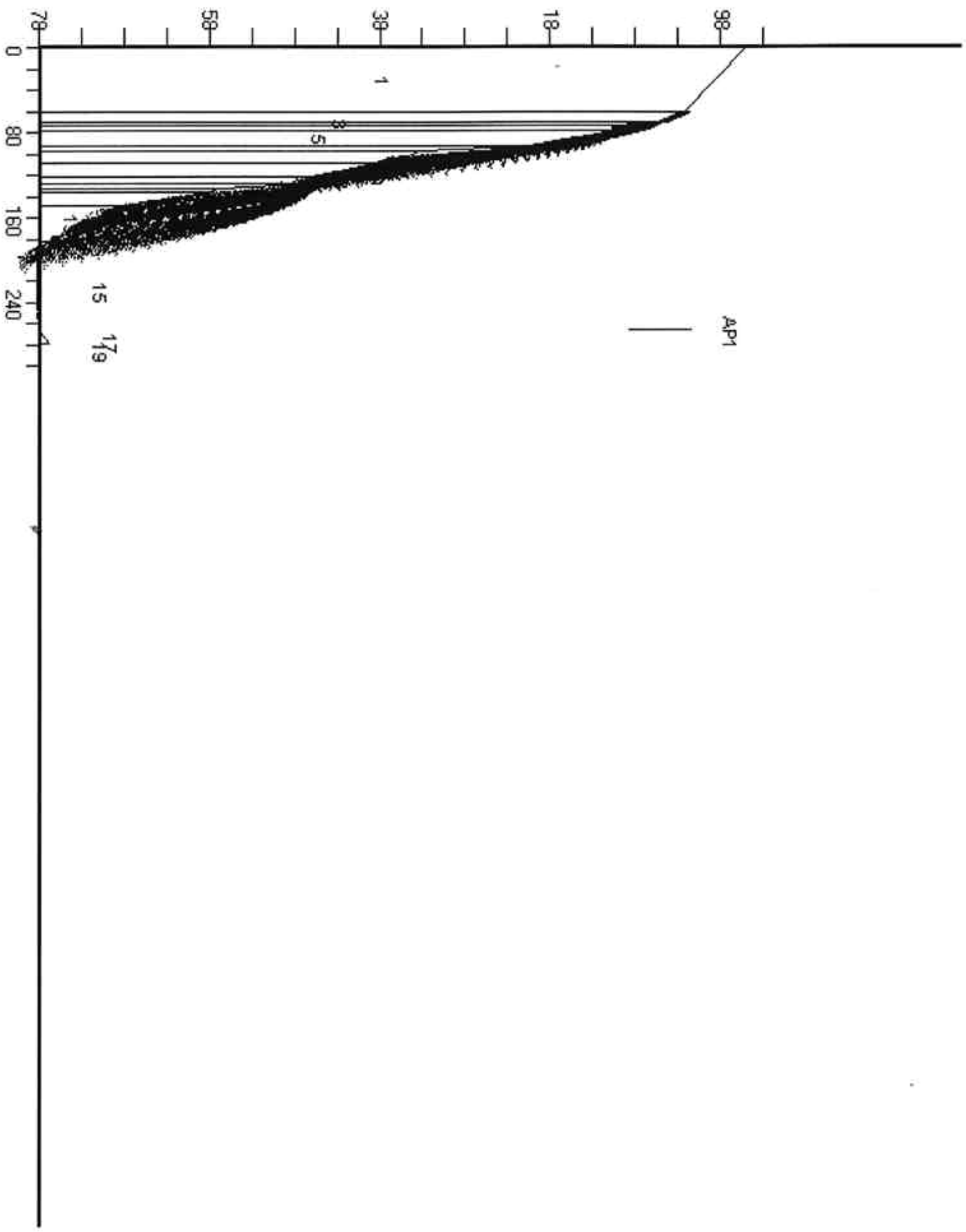
FIGURE 19: MODIFIED CABLE NET SLOPE PROTECTION - FOUNDATION DETAILS

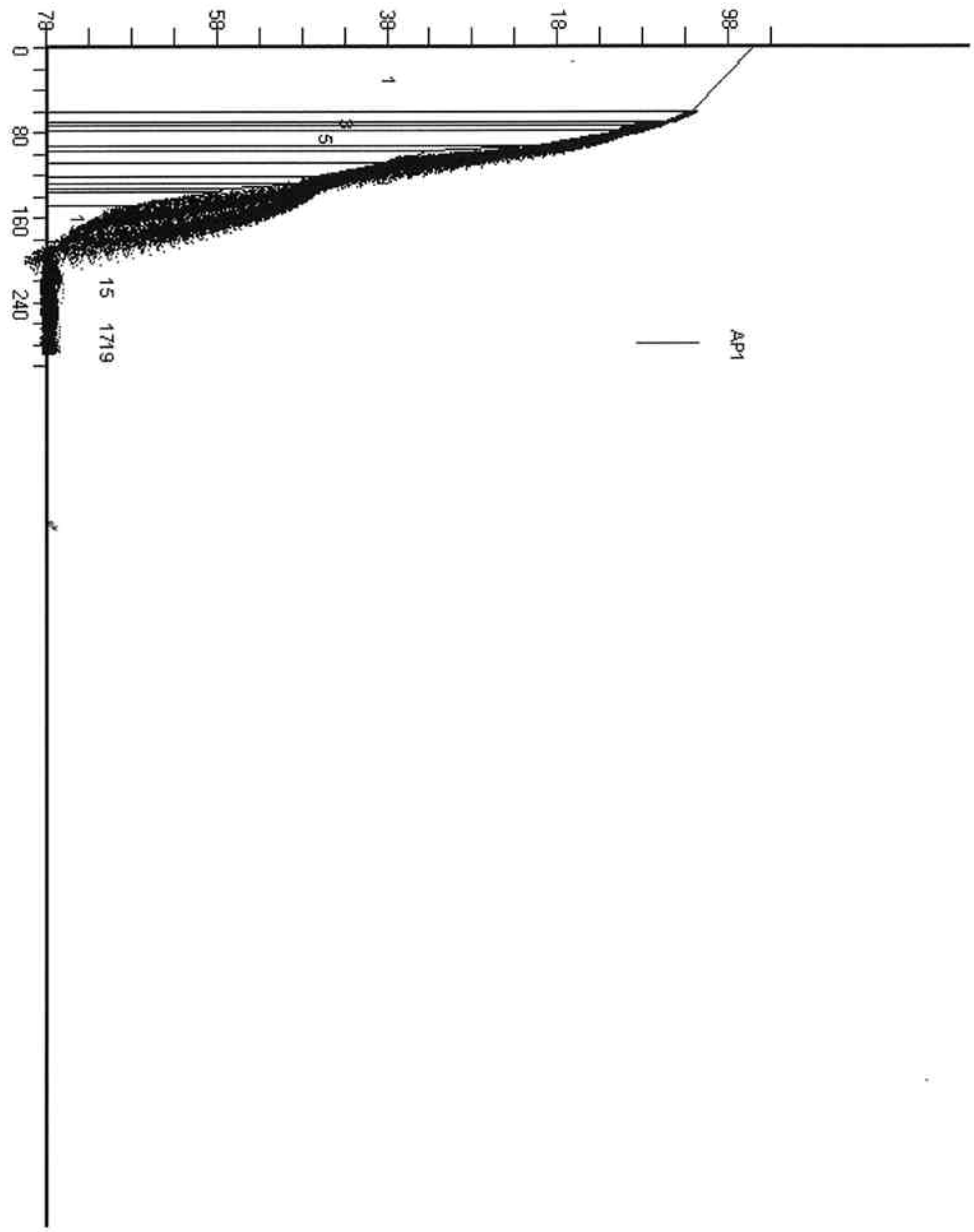
APPENDIX B
(Colorado Rockfall Simulation profiles)



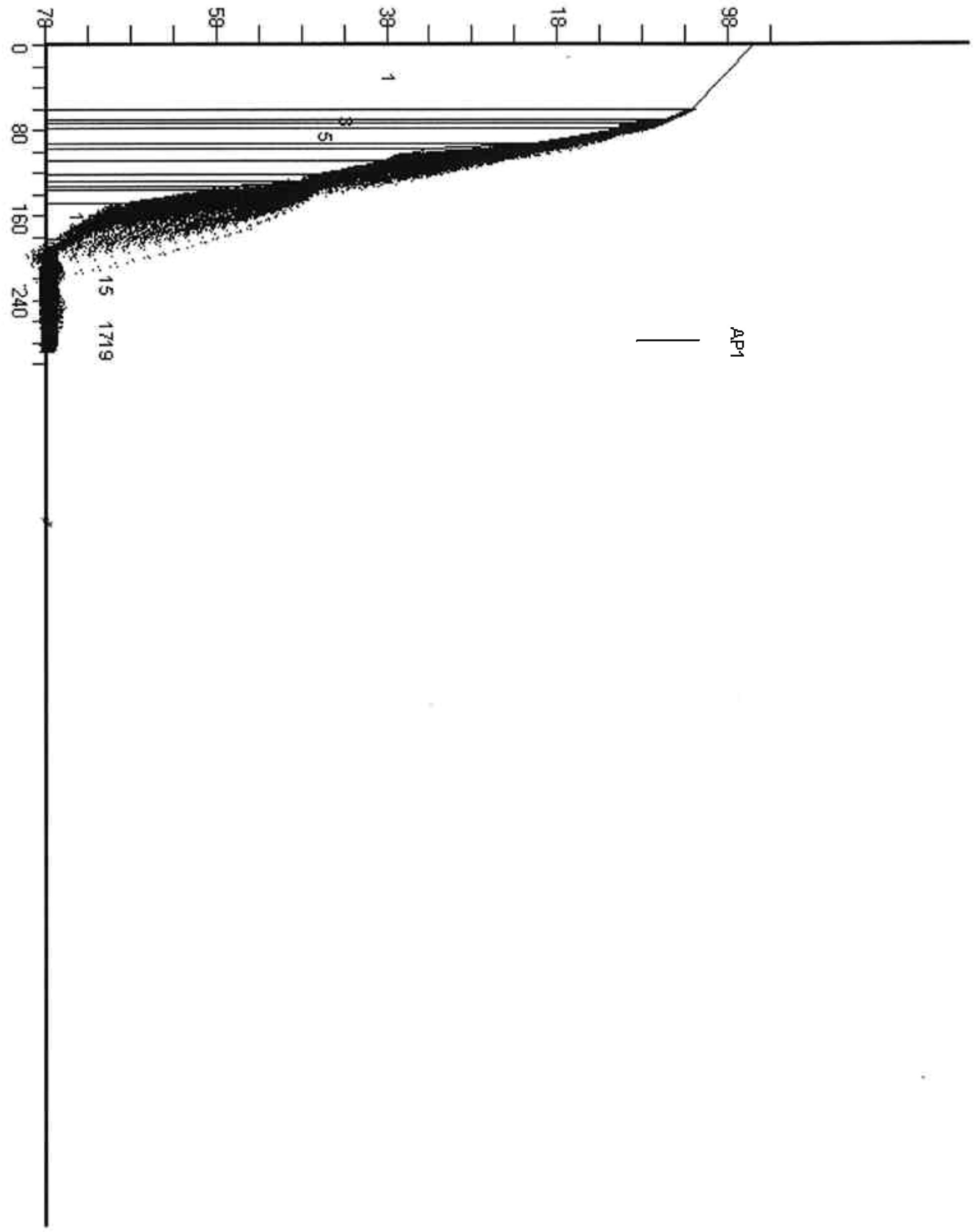
Station 250+50, 3 ft block, originating from top of slope, with an attenuation blanket and ecology block wall/earthen berm for rockfall protection along southbound edge of pavement and analysis point at beginning of berm.



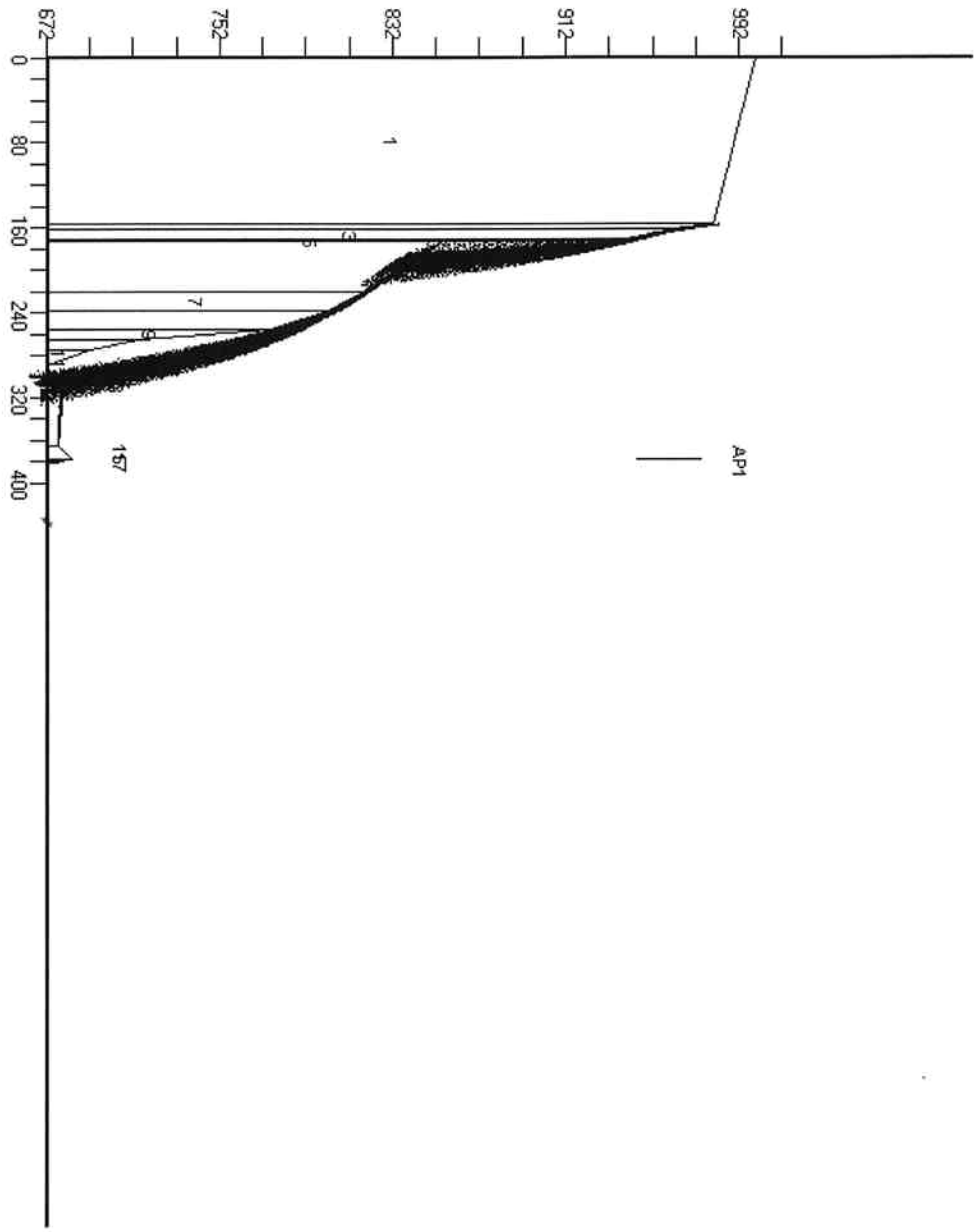
Station 250+50, 6 ft block, originating from top of slope, with an attenuation blanket and ecology block wall/earthen berm for rockfall protection along southbound edge of pavement and analysis point at beginning of berm.



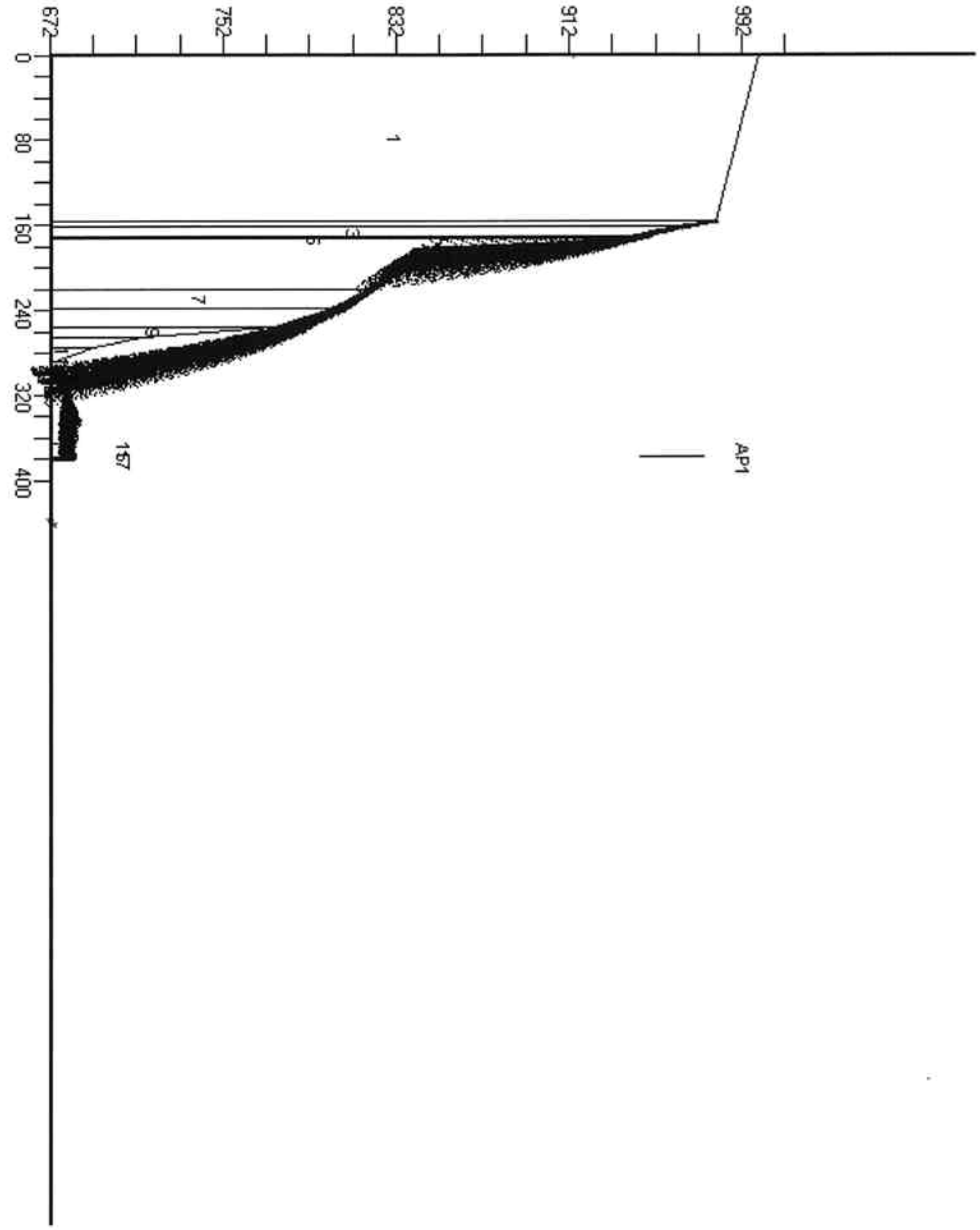
Station 250+50, 6 ft block, no rock fall protection, analysis point at southbound edge of pavement



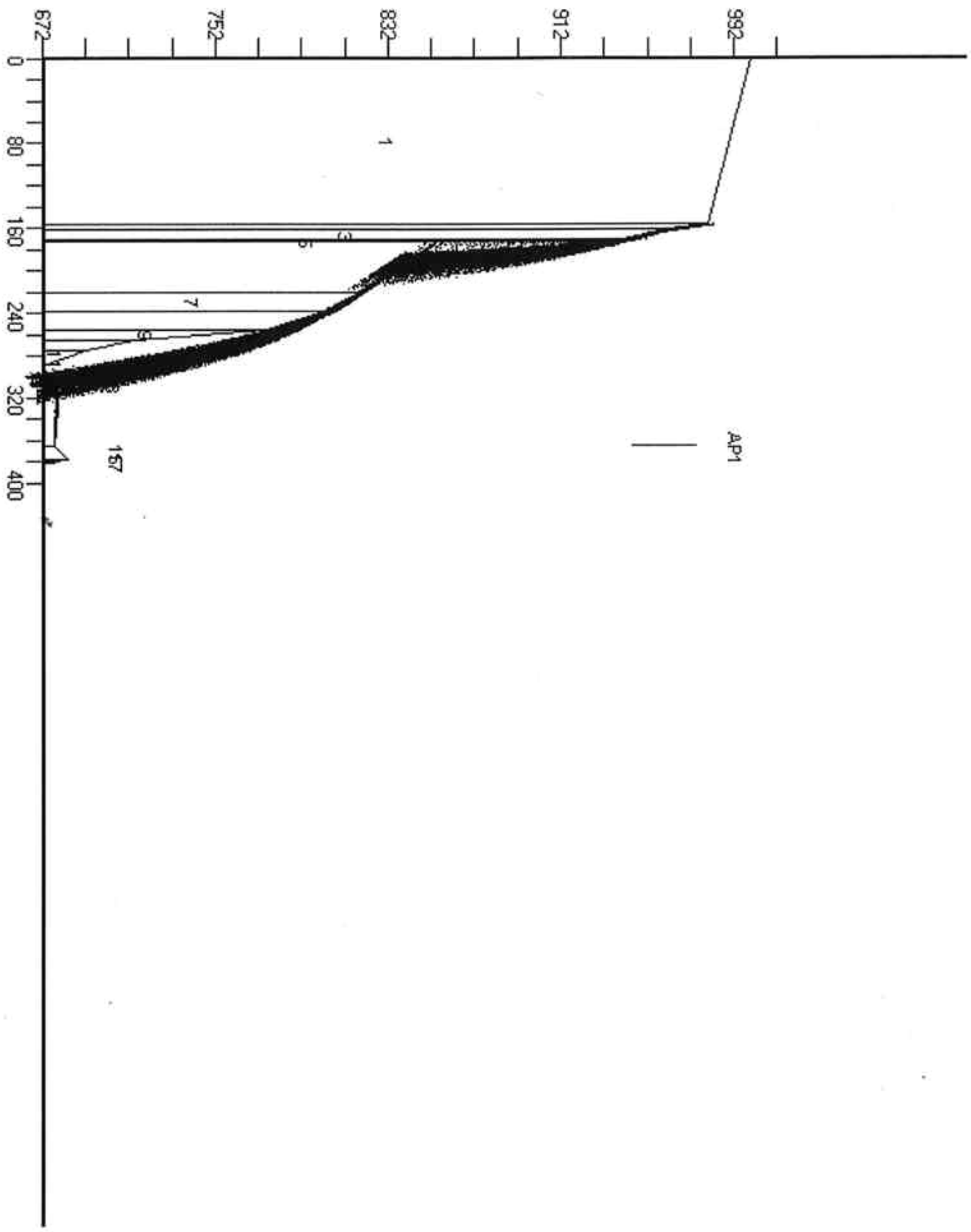
Station 250+50, 3 ft block, no rock fall protection, analysis point at southbound edge of pavement



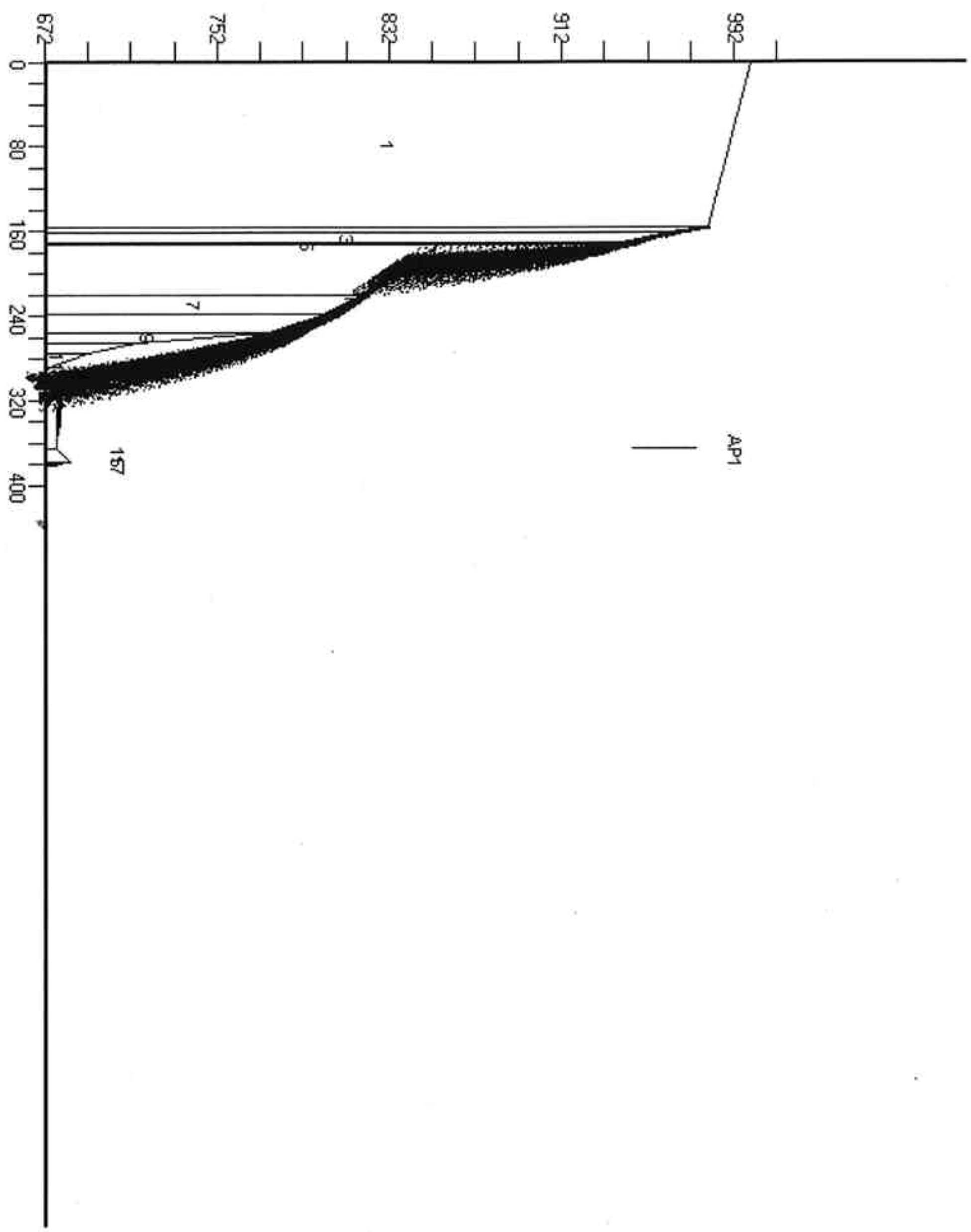
Station 252+90, 6 ft block, no rock fall protection, analysis point at southbound edge of pavement



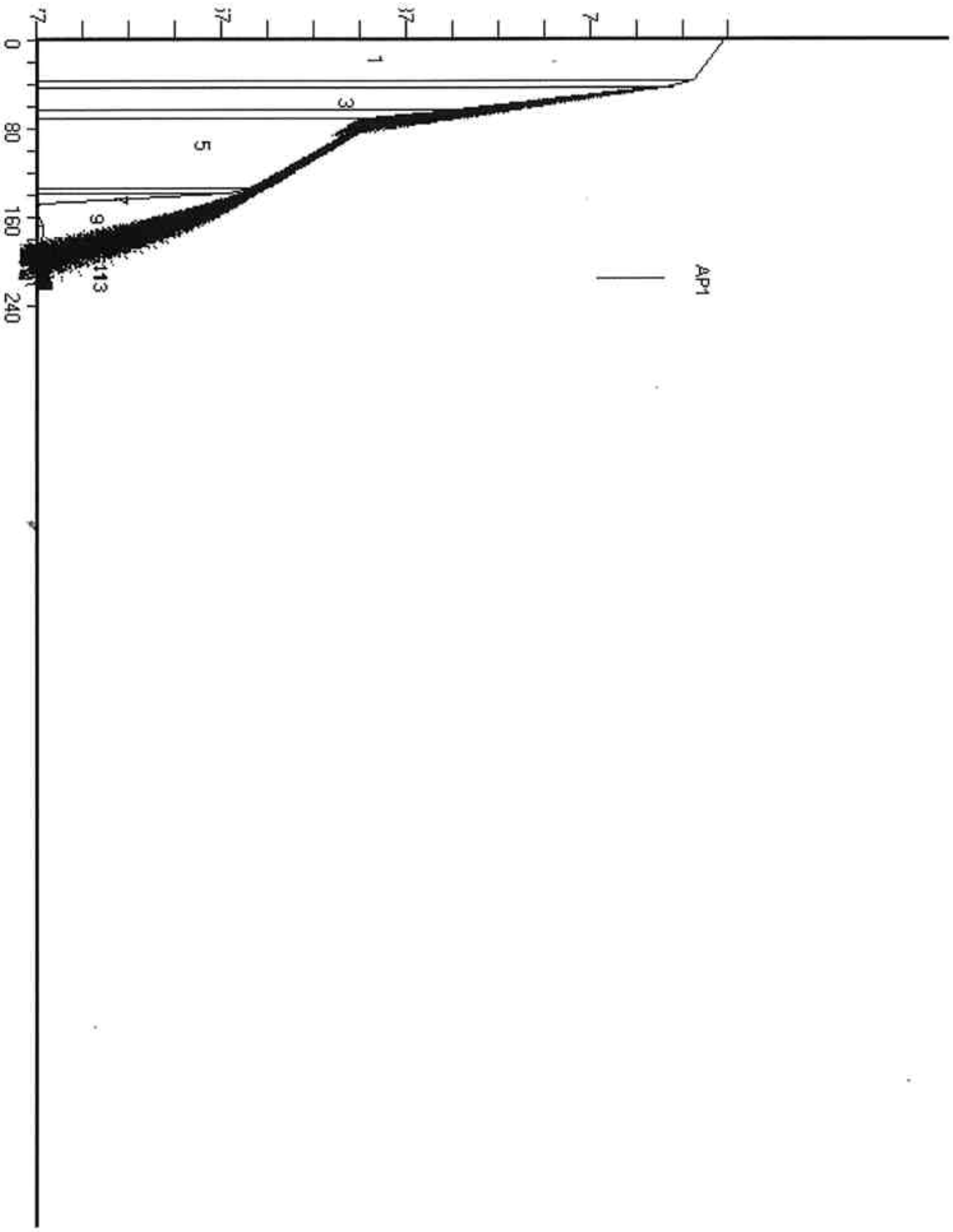
Station 252+90, 3 ft block, no rock fall protection, and analysis point at southbound edge of pavement



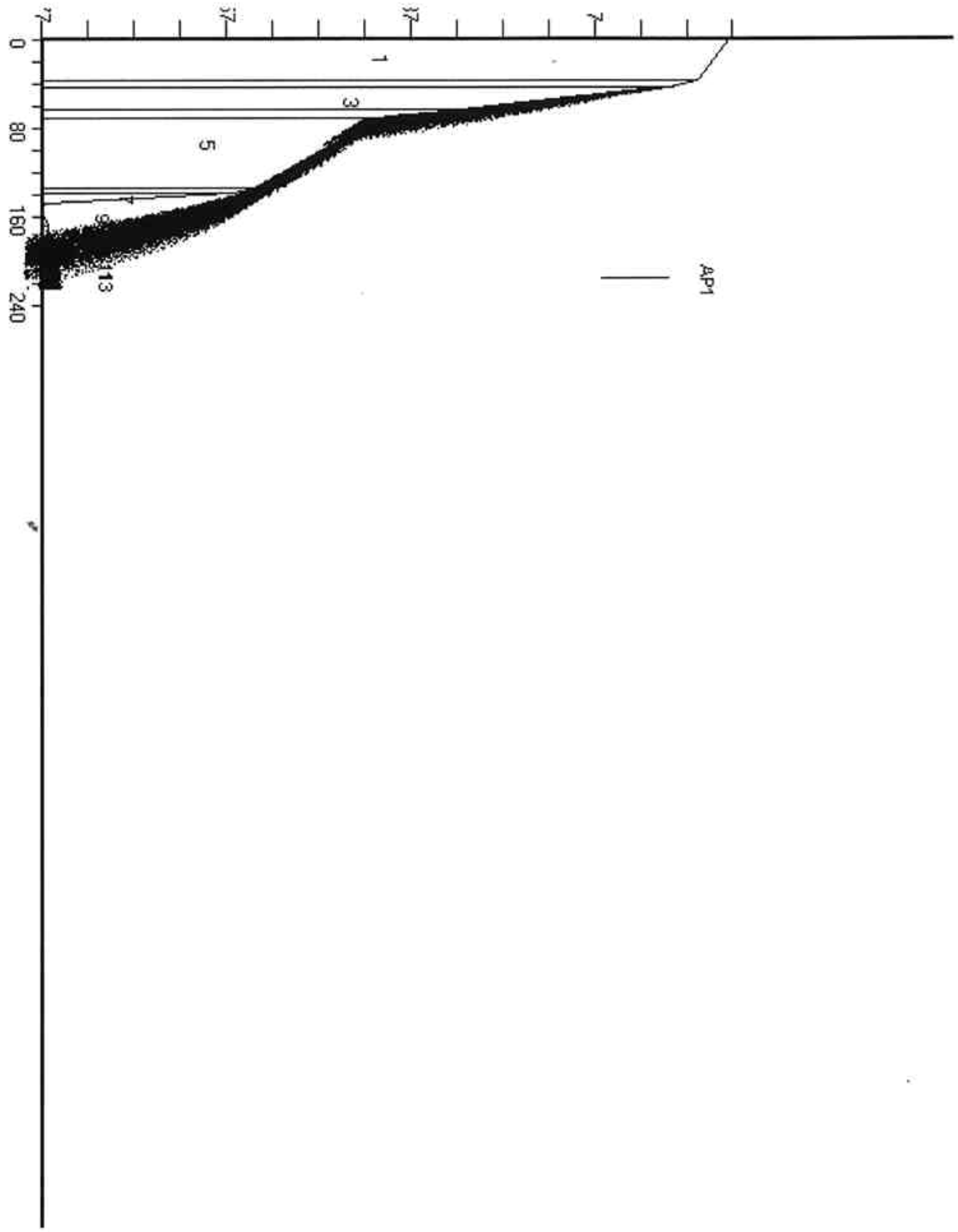
Station 252+90, 6 ft block, attenuation blanket, with a 12' removable rock fall barrier & analysis point at the barrier.



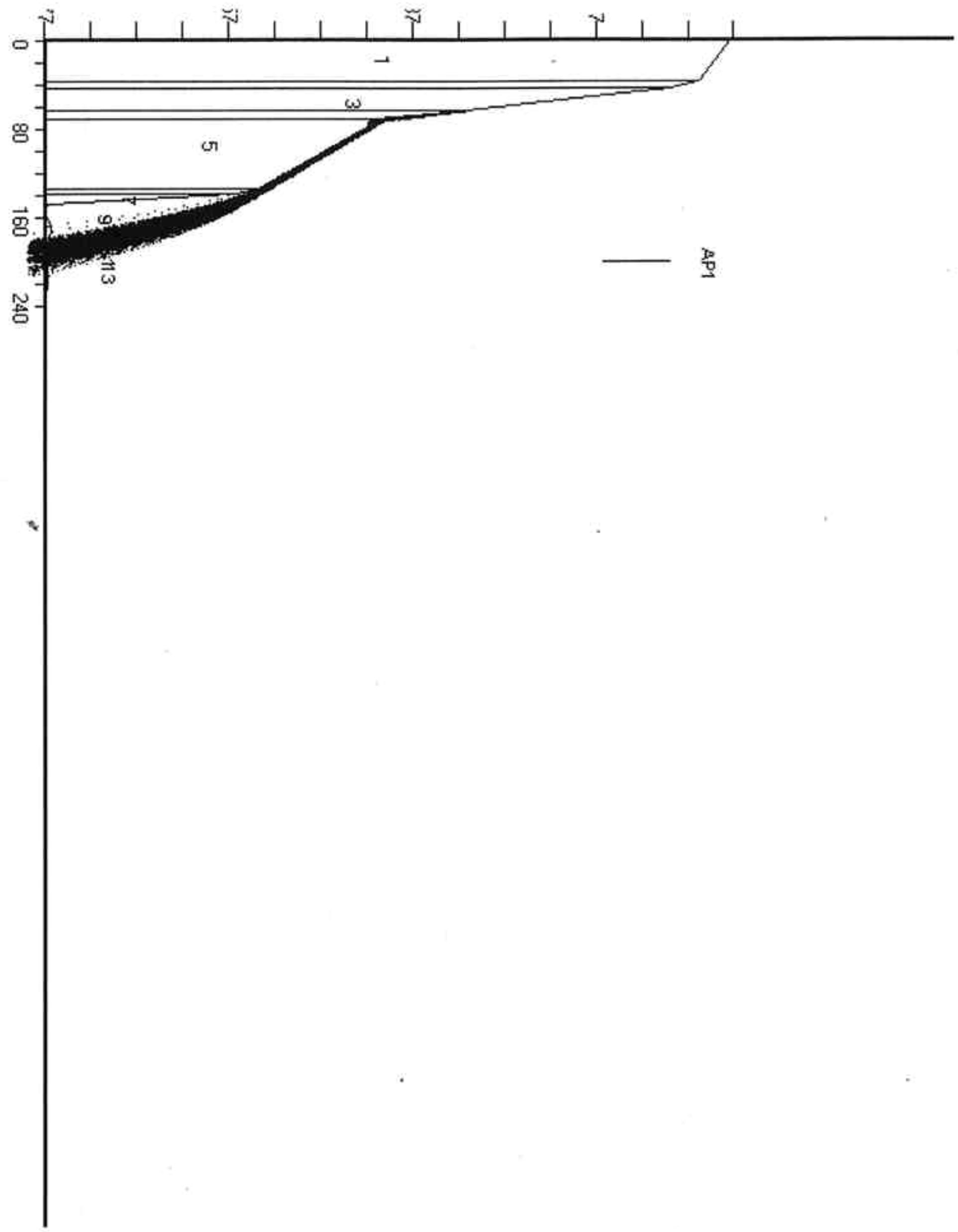
Station 252+90, 3 ft block, attenuation blanket, with a 12' removable rock fall barrier & analysis point at the barrier.



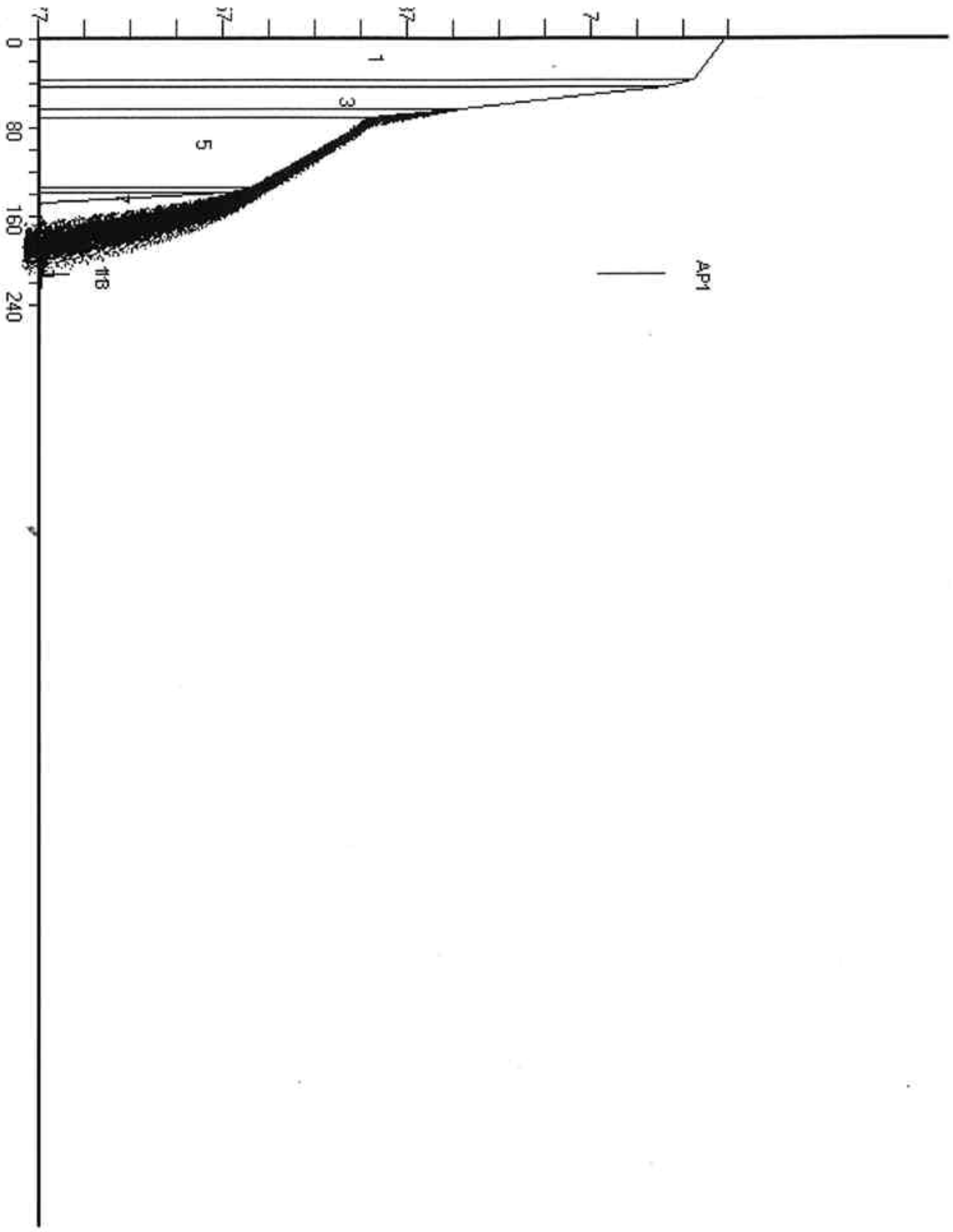
Station 254+00, 6 ft block, no rock fall protection, analysis point at southbound edge of pavement



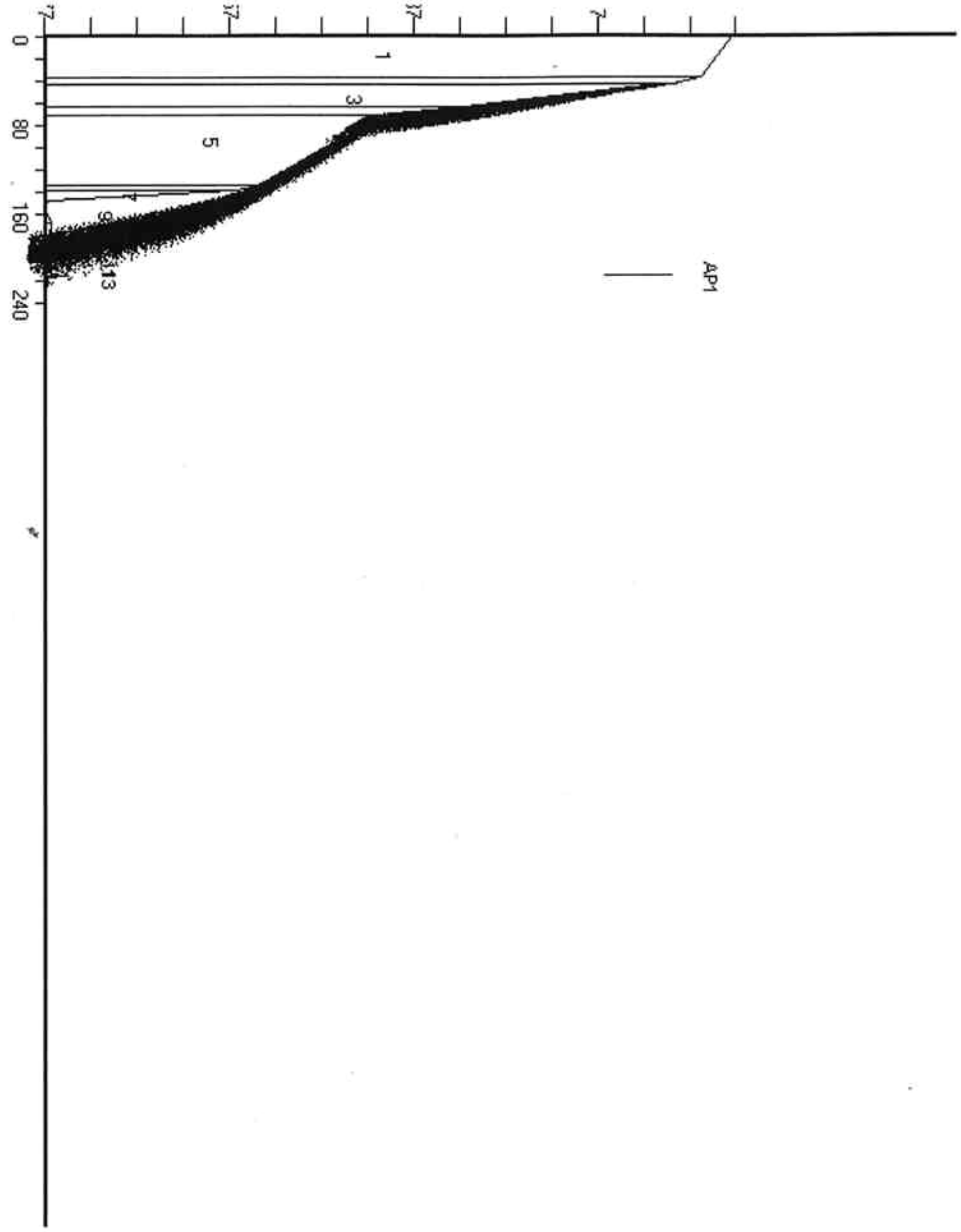
Station 254+00, 3 ft block, no rock fall protection, analysis point at southbound edge of pavement



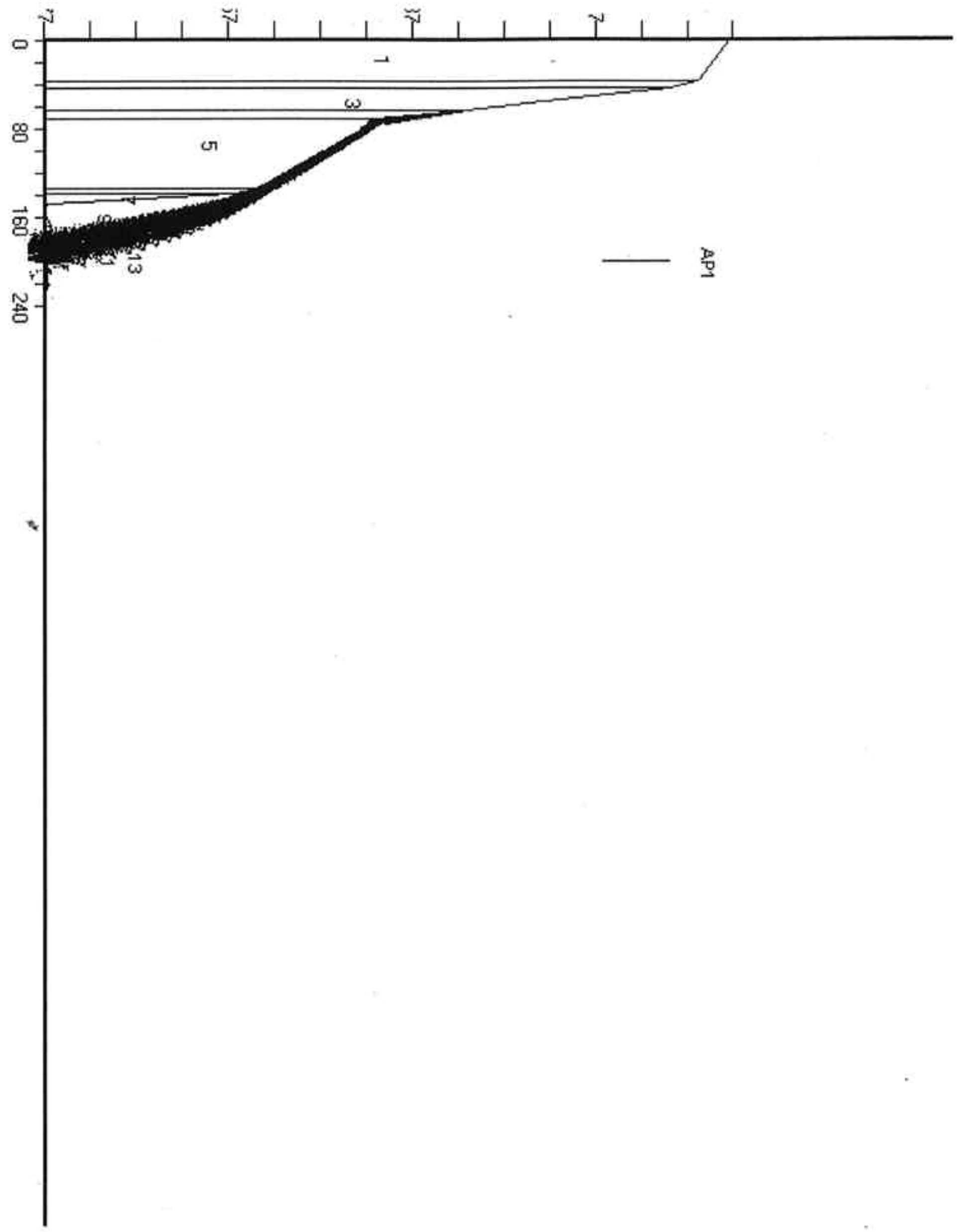
Station 254+00, 6 ft block, attenuation blanket, with a 12' removable rock fall barrier & analysis point at 16 ft from edge of pavement



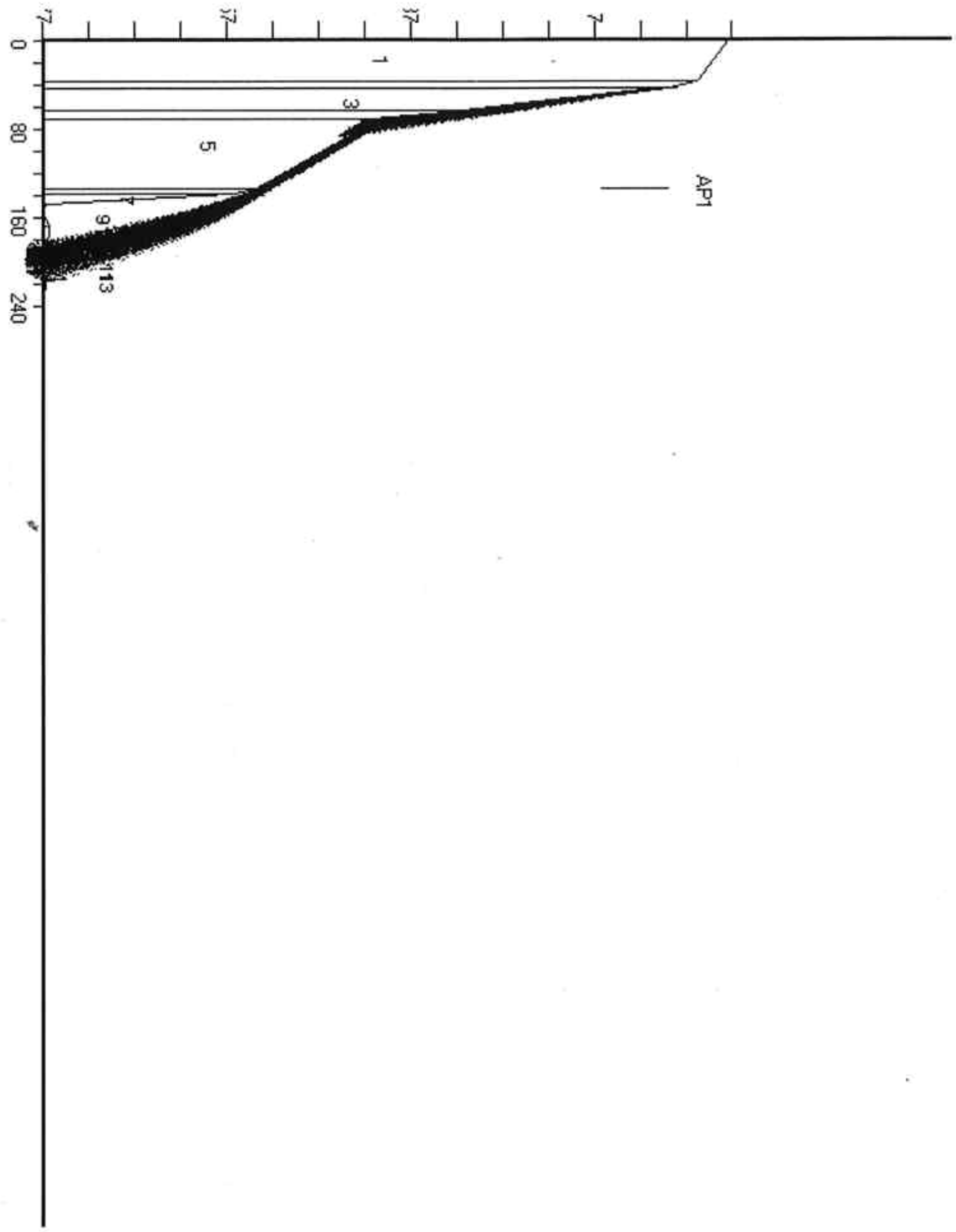
Station 254+00, 3 ft block, originating from the area of the columns, with an attenuation blanket and 12' MRB placed 4 ft from the southbound edge of pavement.



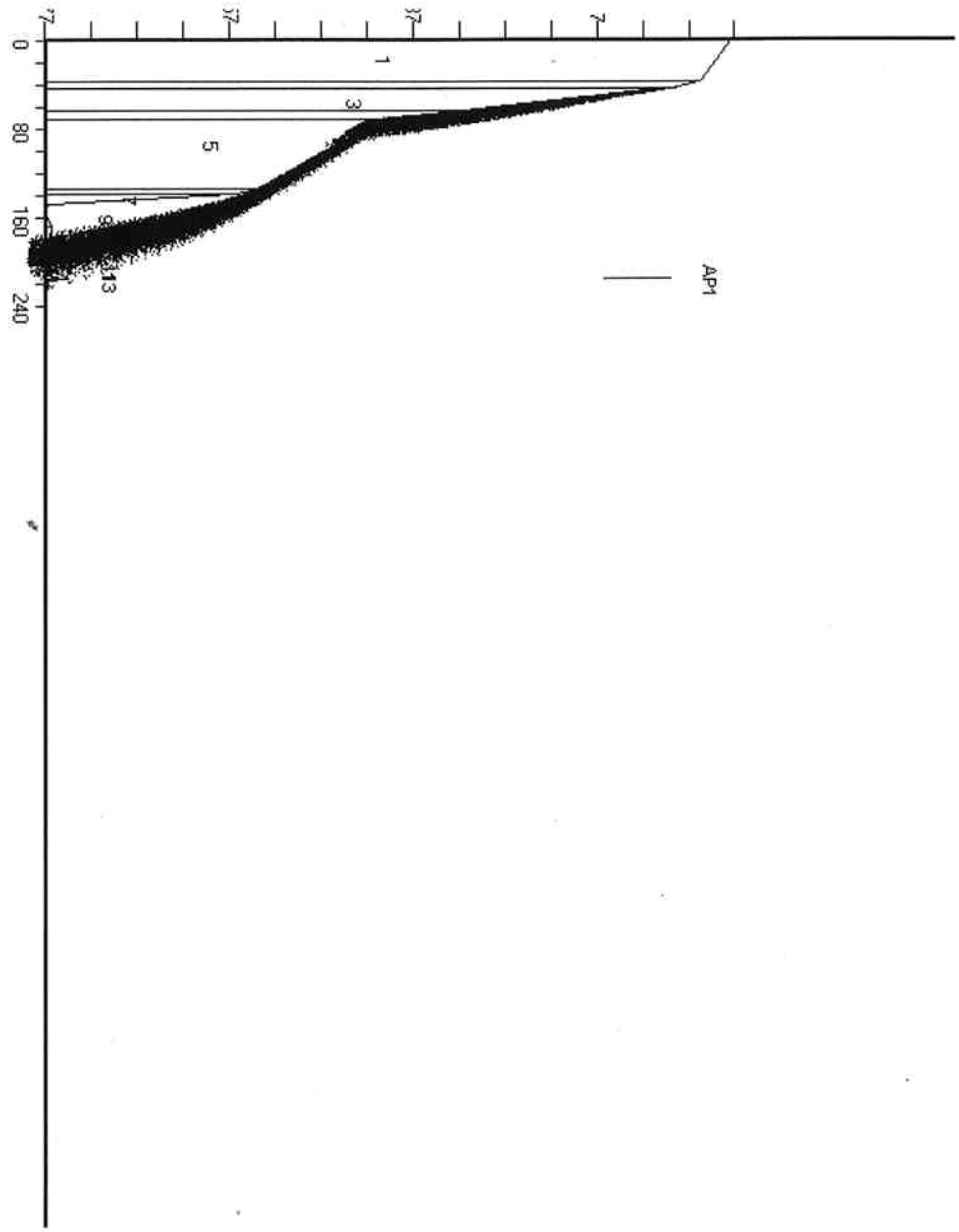
Station 254+00, 3 ft block, originating from the area of the columns, with an attenuation blanket and 9' ecology block wall/earthen berm placed along the southbound edge of pavement.



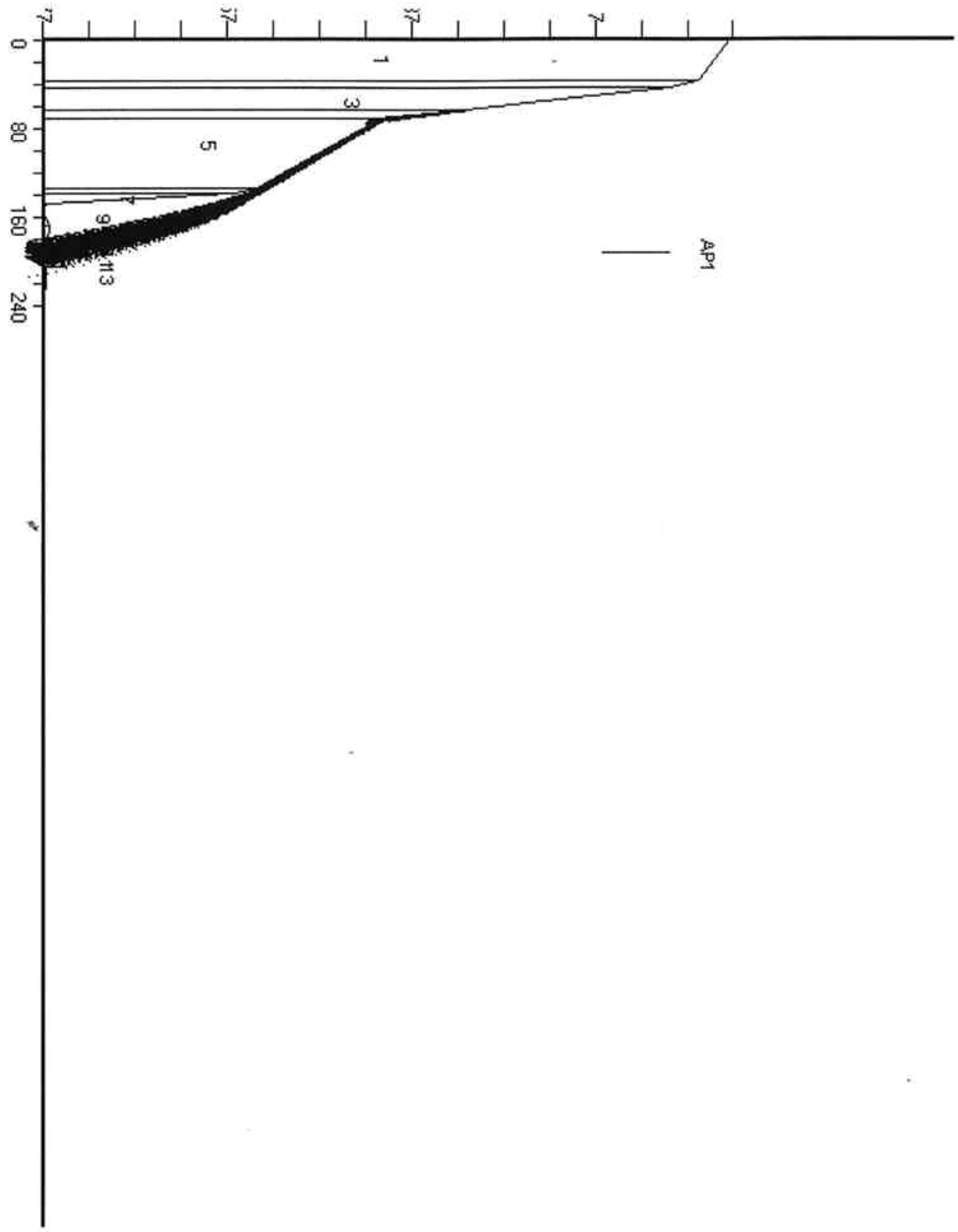
Station 254+00, 3 ft block, attenuation blanket, with a 12' removable rock fall barrier & analysis point at 16 ft from edge of pavement



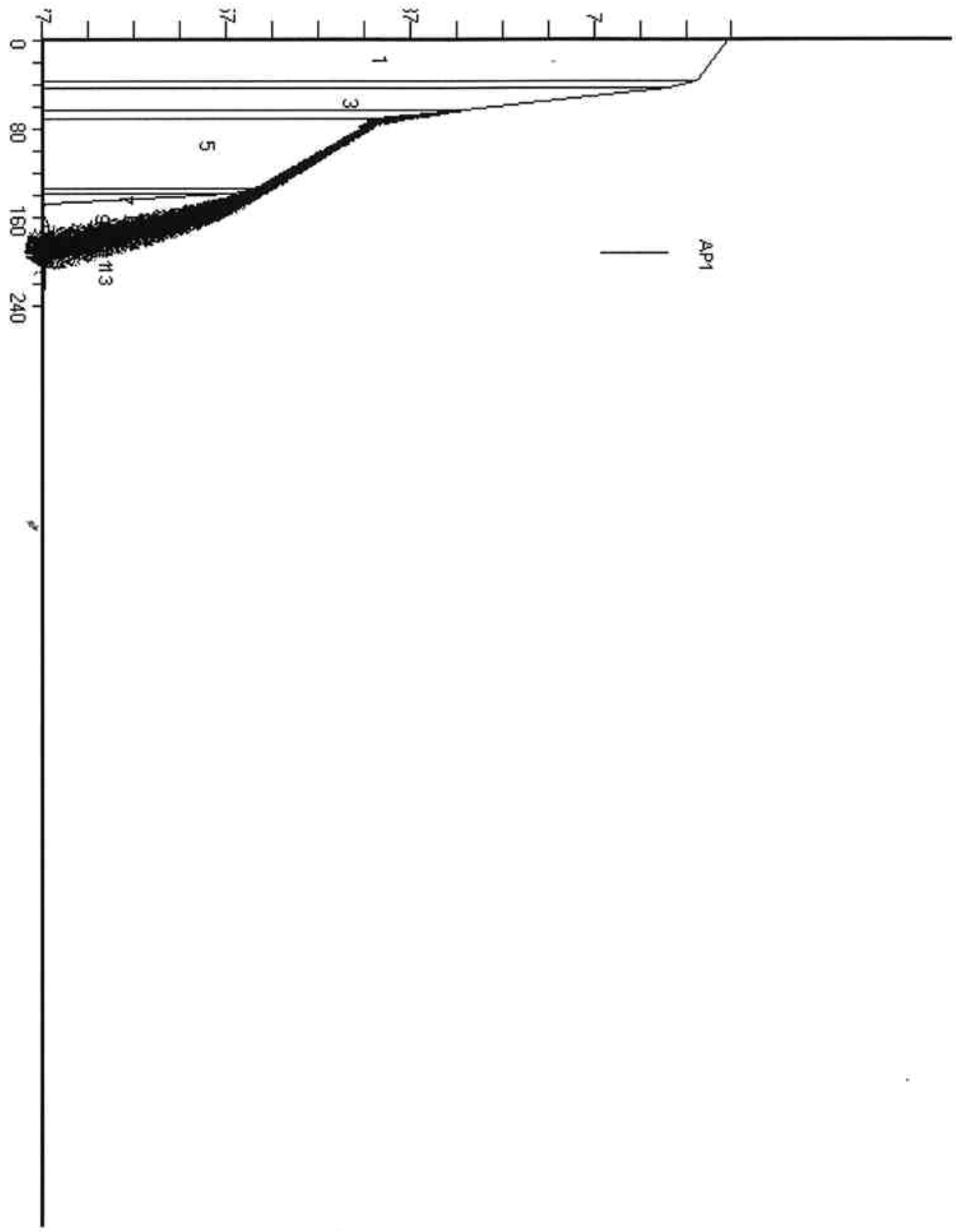
Station 254+00, 6 ft block, attenuation blanket, with a 12' removable rock fall barrier & analysis point at the barrier.



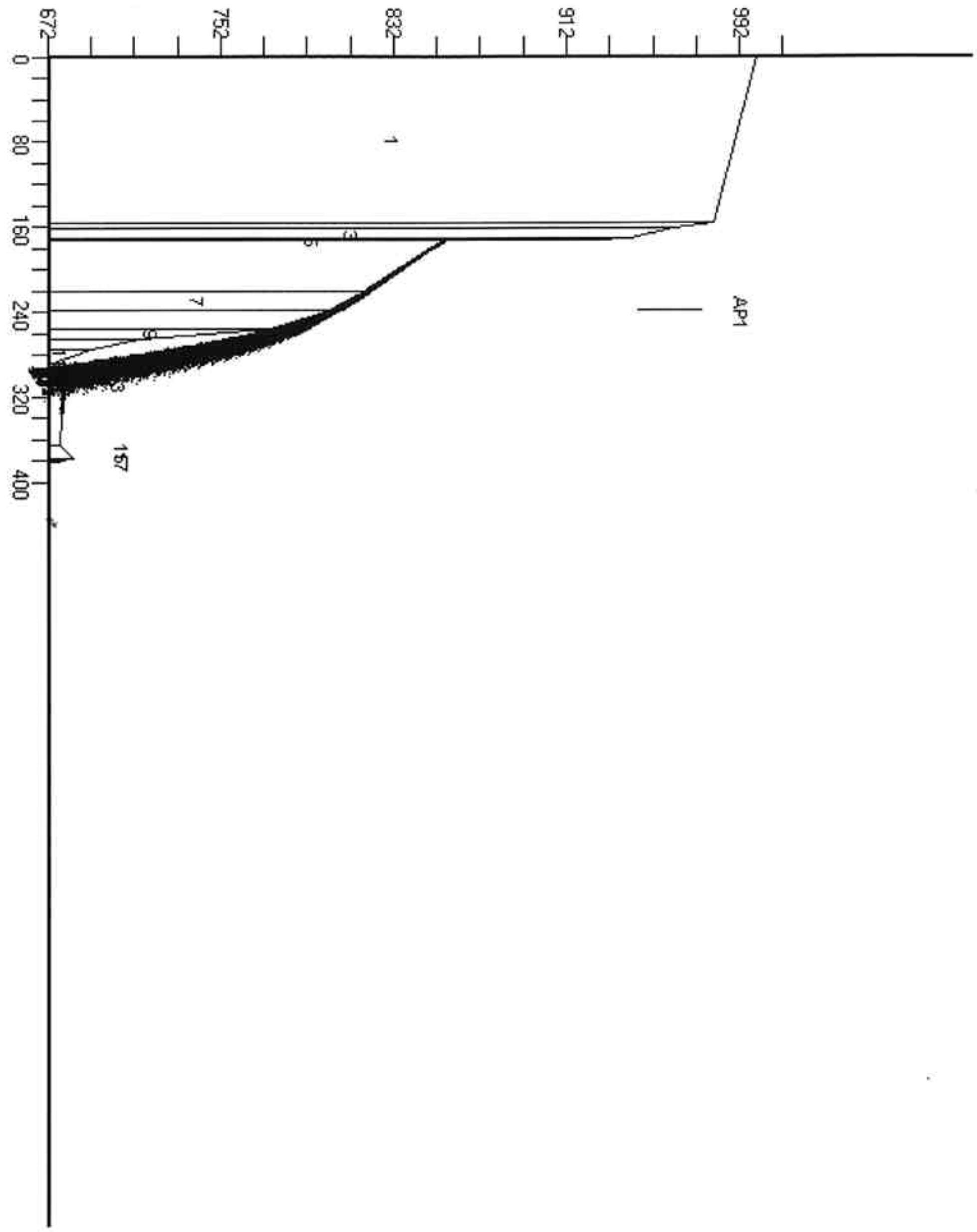
Station 254+00, 3 ft block, attenuation blanket, with a 12' removable rock fall barrier & analysis point at the barrier.



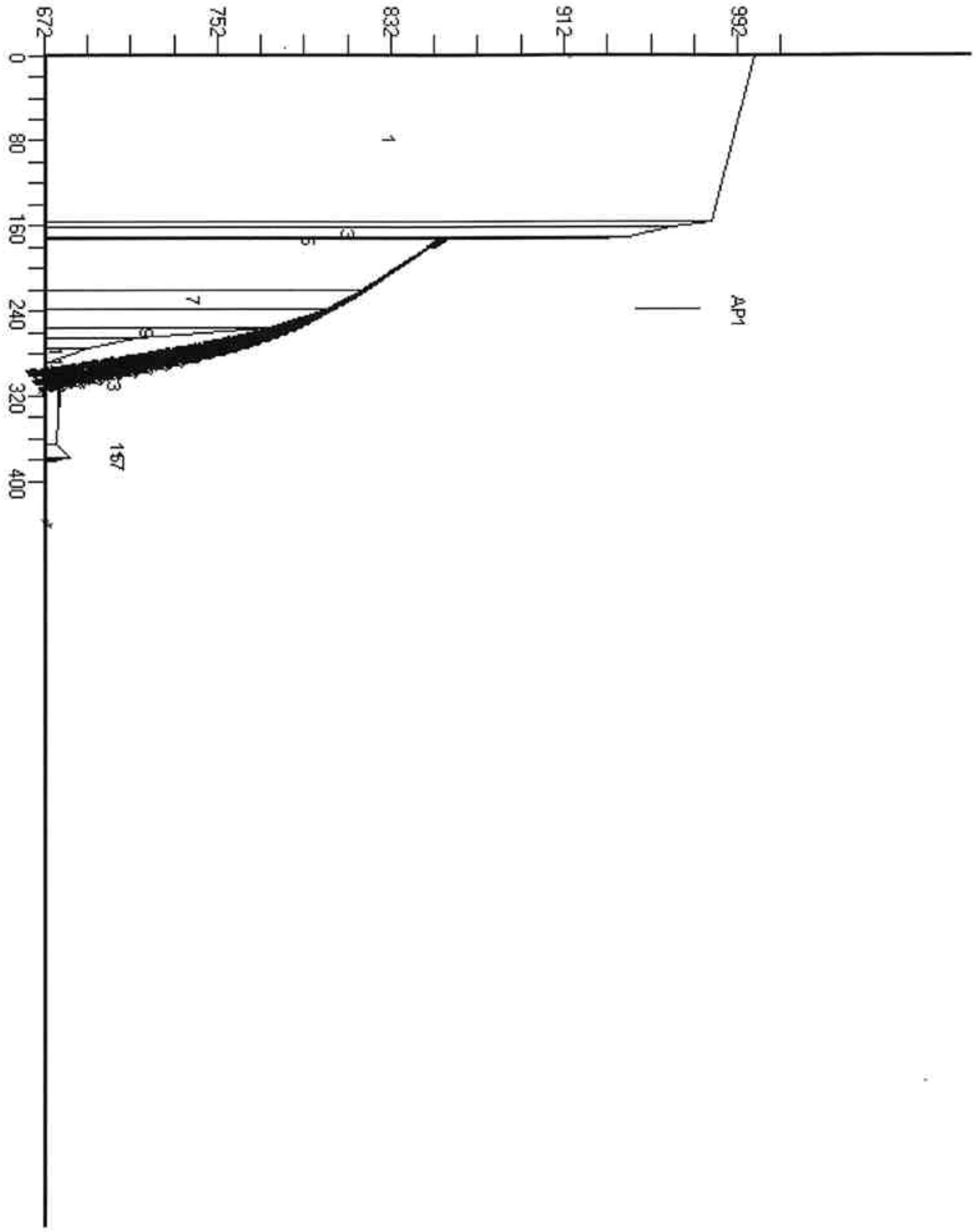
Station 254+00, 6 ft block, attenuation blanket, with a 9' ecology block wall and berm & analysis point at beginning of berm.



Station 254+00, 3 ft block, attenuation blanket, with a 9' ecology block wall and berm & analysis point at beginning of berm.



Station 252+90, 3 ft block, originating from top of bench, with an analysis point at location of modified cable net system.



Station 252+90, 6 ft block, originating from top of bench, with an analysis point at location of modified cable net system.

APPENDIX C
(Special Provisions)

SLOPE SCALING

Description

This work shall consist of the manual removal of vegetation and loose rock and soil on the slope at the locations shown in the Plans or as directed by the Engineer. The Contractor shall provide all materials, equipment, and labor necessary to perform this work.

Submittals

Not less than 2 weeks prior to commencing rock scaling, the Contractor shall provide to the Engineer:

A. The Contractor shall provide written evidence that the rock slope scaling foreman and scalers have performed satisfactory work in similar capabilities for sufficient length of time to be fully qualified to perform their duties. The foreman shall have not less than 1500 hours of demonstrated experience as a scaler. The scalers shall have not less than 1000 hours of demonstrated experience on similar projects.

B. The Contractor shall submit a detailed work plan for each rock slope to be scaled. The plan shall include:

   1. The proposed construction sequence and schedule.
   2. The type of equipment and tools to be used.
   3. The number of scaling crews to be employed on the project. (A scaling crew is defined as one qualified foreman and two qualified scalers.)
   4. Debris removal and disposal plan generated from the scaling work.
   5. Provisions to protect adjacent facilities.

Work shall not begin until the Engineer has approved the appropriate submittals in writing.

Materials

Slope scaling will be done with the use of scaling bar, portable hydraulic wedges, air pillows or other mechanical means. Other hand tools in addition to scaling bars may be used provided they have demonstrated effectiveness to perform the required work by approval of the Engineer.

Construction Requirements
Work shall proceed according to the work plan and schedule submitted by the Contractor prior to commencement of work. The size of the crew, defined as a foreman and two qualified scalers, shall be maintained at all times.

Slope scaling shall start at the top of the slope and work shall proceed down slope, removing loose rock and soil as the work progresses. Tree removal shall be included as scaling. In general, any trees within 10 feet of the slope crest shall be flush cut and the root wad left intact. Tree felling shall be completed prior to performing other scaling work.

The extent of the slope scaling will be determined by the Engineer and/or be specified in the Plans.

All rock and debris produced by the scaling operation shall be removed by the Contractor and hauled to a site specified in the contract. See Special Provision **DEBRIS REMOVAL INCLUDING HAUL.**

Measurement
Slope scaling will be measured by the crew hour. Debris removal will be by the cubic yard in the hauling conveyance at the point of removal from the roadway. See Special Provision **DEBRIS REMOVAL INCLUDING HAUL.**

Payment
The unit contract price per crew hour for slope scaling shall be full pay for performing the work as specified.

DEBRIS REMOVAL INCLUDING HAUL

Description
This work consists of removing existing debris from the roadway or material generated from slope scaling and trim blasting operations.

Construction Requirements
The Contractor shall remove all existing and slope scaling- / trim blasting-related debris within the project limits and/or as directed by the Engineer. The Contractor shall also haul and place debris at a specified location.

Measurement
Debris removal will be measured by the cubic yard in the hauling conveyance at the point of removal from the roadway.

Payment
The unit contract price per cubic yard for "Debris Removal Including Haul" shall be full pay for performing the work described including furnishing the equipment, materials, and labor required to load, haul, and place the debris at the specified location.

TYPE 1 ROCK DOWEL

Description

This work shall consist of the installation of untensioned Type 1 rock dowels at the locations and orientations designated in the Plans or by the Engineer. The Contractor shall select and construct the dowels to carry a 25 kip design load and supply all materials, equipment, and labor to test and install the dowels. The Engineer will designate the orientation and minimum length of the dowel required.

Submittals

Not less than two weeks prior to commencing the rock doweling, the Contractor shall submit in writing to the Engineer for approval:

A. The Contractor shall provide written evidence that the foreman and drill operator have performed satisfactory work in similar capacities elsewhere. The foreman shall have installed a minimum of 3000 lineal feet of untensioned and/or tensioned rock anchors on a minimum of 5 projects over 5 years, and the drill operator shall have installed a minimum of 1000 lineal feet of untensioned and/or tensioned rock anchors on a minimum of 3 projects over 5 years.

B. The Contractor shall submit a detailed plan for the rock doweling to include:

1. The proposed construction sequence and schedule.

2. The proposed drilling method and equipment.

3. The proposed drill hole diameter.

4. The proposed anchor steel/tendon, couplers, bearing plate, anchor unit, flat washer, and beveled washer specifications including manufacturer's data sheets, catalog cuts and mill certificates.

5. The proposed cement grout mix design including manufacturer's data sheets and catalog cuts and the procedures for placing the grout.

6. The proposed construction method for upwardly inclined anchors.

7. The proposed corrosion protection for the rock dowel system. This shall include written certification and statement of manufacturer's compliance for corrosion-resistant bar coating.

8. The calibration data for each load cell, test jack, pressure gauge and master pressure gauge to be used in the proof testing. An independent testing laboratory shall have performed the calibration tests within 60 calendar days of the date submitted.

9. The proposed stressing procedures and stressing equipment to proof test the dowels.

Work shall not begin until the Engineer has approved the appropriate submittals in writing.

Materials
All rock bolts, including anchorage, bearing plates, couplers, corrosion protection, and other appurtenances, shall be products of a manufacturer regularly engaged in the manufacturing of materials for the construction of rock dowels. Dowels shall be fabricated from deformed steel bars complying with WSDOT Standard Specification 9-07.

Anchor bar steel shall not be precut at the factory to lengths shown in the Plans, but rather be delivered in bulk lengths and field cut to the appropriate length. Anchorage devices shall be capable of developing 95 percent of the minimum guaranteed ultimate tensile strength of the pre-stressing steel. The anchorage devices shall conform to the static strength requirements of Section 3.1.(1) and Section 3.1.8(1) of the Post-tensioning Institute "Guide Specification for Post-tensioning Materials."

Each rock dowel shall be fitted with a bearing plate and nut. The bearing plate shall be of mild steel, not less than 0.25 inches in thickness and not less than 4 inches square. A minimum 8 inch- square bearing plate shall be used for rock surfaces that are very weak and/or highly weathered, or where anchoring through and bearing against shotcrete. The plate shall have a central hole large enough to fit easily over the dowel while maximizing the average bearing surface for the washer and the nut. Spherical seating of the nut is not required. Beveled washers shall be used to accommodate non-perpendicular installations.

Anchor bar steel shall be provided with either fusion-bonded epoxy coating or hot dip galvanizing for corrosion protection. Epoxy coating shall be applied in accordance with ASTM A 934 and shall have a minimum thickness of 10 mils plus or minus 2 mils. Patching material, compatible with the epoxy coating and inert in cement grout, shall be supplied with each shipment. Extreme care shall be taken in the handling of epoxy-coated bars to prevent coating damage and embrittlement. Field handling procedures for epoxy-coated bars shall be in general accordance with ASTM D 3963 including providing padding between contact points during storage and lifting and covering coated bars to minimize ultraviolet exposure. Hot dip galvanizing shall comply with ASTM A 153 and shall have a minimum thickness of 3.9 mils.

Cement grout shall be a proven, non-shrink material capable of permanently developing the bond and internal strength necessary for the required dowel capacity. The use of epoxy or polyester resin as bonding agents is not allowed. If requested by the Engineer, a sample of the cement grout shall be provided for testing.

Corrosion protection paint shall conform to Section 9-08.2 for Formula A-9-73 - Galvanizing Repair Paint, High Zinc Dust Content.

Construction Requirements

Work shall proceed according to the plan and schedule submitted by the Contractor prior to the commencement of the work.

The Engineer shall specify the location, orientation, and minimum length of each rock dowel. The rock dowel shall be installed within five degrees of the specified angle. Unless otherwise specified, the angle of installation shall be perpendicular to the rock face and inclined slightly downward. If the axis of the rock dowel is not close to perpendicular to the rock face or within the angle provided by the beveled washer, or the rock beneath the bearing plate is not sound, a bearing pad approved by the Engineer shall be constructed at no additional cost to the State, so that the rock dowel is not bent when tensioned. In all cases, at least three quarters of the bearing plate shall be in contact with the rock face.

The dowels shall be handled and stored in such a manner as to avoid damage or corrosion of the coating and the steel. Damage to the dowel steel as a result of abrasion, cuts, nicks, welds, and weld splatter will be cause for rejection. The dowels shall be protected from dirt, rust, and harmful substances. A light coating of rust on the steel is acceptable. If heavy corrosion or pitting is noted, the Engineer will reject the rock dowel.

Prior to installation all mill scale, flaking rust and grease shall be removed from the steel. The entire length of the rock dowel shall be encapsulated in cement grout for a second level of corrosion protection. All exposed parts of the dowel, bearing plate and nut on the surface shall be painted with approved corrosion protection paint or epoxy patching compound.

The use of hand drills for advancing the anchor hole is not allowed without written permission by the Engineer and demonstrated effectiveness by the Contractor.

The drill hole shall be sized to provide a minimum of 0.5 inches of grout cover around the bar. The Contractor shall flush the drill hole of all drill cuttings and debris with compressed air prior to the installation of the rock dowel. Holes drilled for rock dowels in which dowel installation is considered by the Engineer to be impractical shall be re-drilled at the Contractor's expense.

The grout equipment shall produce a grout free of lumps and undispersed cement. The pump shall be equipped with a pressure gauge near the discharge end to monitor grout pressures. The grouting equipment shall be sized to enable the grout to be pumped in one continuous operation. The grout shall be injected from the lowest point of the drill hole. The quantity of the grout and the grout pressures shall be recorded.

Centralizers shall be placed on the bar on 10-foot centers prior to grouting with a minimum of two centralizers per anchor. The lower centralizer should be located within one foot of the end of the bar/tendon. Sufficient grout will be placed in the drill hole to ensure full encapsulation of the dowel.

When the cement grout has reached final set, the Contractor shall install the bearing plate, washers and nut. The nut shall be torqued to a nominal 100 foot-pounds to insure proper seating against the rock face. The end of the completed rock dowel shall be trimmed to within 6 inches of the rock face.

At the discretion of the Engineer, up to 5 percent, but not less than three rock dowels, of the installed rock dowels shall be proof tested. The Contractor shall conduct the proof test, and the Engineer will interpret the results. The rock dowel shall be tensioned to 25,000 pounds with a calibrated hollow-ram hydraulic jack using a bar extension and coupler attached to the rock dowel and held for 10 minutes. If no loss of load occurs over this time period, the rock dowel is acceptable. The Engineer may require additional proof of testing beyond the 5 percent maximum, if rock dowels fail the proof testing. All failed rock dowels shall be replaced with an additional rock dowel installed in a separate hole. No payment will be made for rock dowels that fail or for additional proof testing.

Measurement
Rock dowels will be measured per lineal foot of rock dowel installed and accepted.

Payment
The unit contract price per lineal foot for "Type 1 Rock Dowel" shall be full pay for performing the work as specified. The cost for the performance and proof testing shall be included in the unit bid price for "Type 1 Rock Dowel". The unit contract price shall include grout-take up to 200 percent of the drilled hole volume calculated from the hole diameter and length. For grout takes greater than 200 percent in any specific hole, the Contractor shall be reimbursed under bid item "**Force Account Grout Exceedance**". Wasted grout will not be measured for payment. For measurement of grout volume injected, the Contractor shall supply a meter or other method satisfactory to the Engineer.

8/14/2007

MODIFIED CABLE NET SLOPE PROTECTION

Description

This work consists of installing and testing anchors and suspending cable net panels backed with pvc-coated and colorized wire mesh on steel posts in accordance with these specifications and the details shown in the Plans.

Submittals

Not less than two weeks prior to the placement of the modified cable net slope protection, the Contractor shall submit in writing to the Engineer for approval:

1. The supplier of the cable nets. The supplier must be a pre-approved provider of cable nets and included in the New Products list. Suppliers that are not pre-approved must provide written evidence that the cable nets have performed satisfactorily in similar capacities elsewhere.

2. The inclusive list and catalog cuts for the appurtenances to be used for the anchors, support system, and wire mesh fasteners (i.e., anchor bars, grout, wire rope, clips, thimbles, ferrules, steel rings, fasteners, etc.)

3. The color for the pvc-coated wire mesh and the steel support posts.

4. The plan for installing anchors and verifying their capacity. The calibration data for the stressing device to proof test the anchors shall be provided. An independent testing laboratory shall have performed the calibration tests within 60 calendar days of the date submitted.

5. The plan for fabricating and placing the cable nets and wire mesh on the slope.

Work shall not begin until the Engineer has approved the appropriate submittals, in writing.

Materials

The cable net panels shall meet the following criteria:

Panel Size:	12 ft x 25 ft
Grid Size:	no larger than 12 inch x 12 inch
Seam Rope:	no smaller than 5/16 inch diameter

Cable nets shall be braided with high strength, corrosion resistant clips made from a minimum 0.08 inch (2 mm) thickness plate. The clips shall be pressed on so as not to slip when manually stretched or during the placement of the nets. The clips must be secured in the manner intended by the manufacturer while not damaging the wire ropes. The Engineer shall reject even slightly damaged nets insofar as they could endanger the integrity of the system.

All wire rope shall be galvanized conforming to the requirements of ASTM A 603 Class A. The ¾ inch nominal wire rope shall be of independent wire rope class (IWRC) construction 6x19 and have a normal breaking strength of 52,900 pounds. The 5/16 inch nominal wire rope shall be of galvanized aircraft cable (GAC) construction 7x7 (or 7x19) having a normal breaking strength of 9,200 pounds, respectively.

The wire mesh used to back the cable net panels shall meet Section 9-16.4(2) of the Standard Specifications with the following revision:

> The phrase "*…3 ½ inches x 5 ½ inches diamond mesh chain link…*" shall be replaced with "*…2 inch chainlink or 8 x 10 double-twisted hexagonal wire mesh*".

The wire mesh shall be pvc-coated and colorized to match the surrounding ground conditions.

Hardware shall meet Section 9-16.4(4) of the Standard Specifications with the revision of being sized for ¾ inch diameter wire rope instead of ½ inch diameter wire rope. Steel support posts shall be galvanized or painted with corrosion protection paint.

Fasteners for attaching the wire mesh to the cable nets shall be of high tensile steel.

Anchors shall be one of those specified in the Plans, and all steel components shall be galvanized. Cement grout shall be proven, non-shrink materials capable of permanently developing the bond and internal strength necessary for the specified tensioning.

Corrosion protection paint shall conform to Section 9-08.2 for Formula A-9-73 - Galvanizing Repair Paint, High Zinc Dust Content.

Construction Requirements
Modified cable net slope protection shall be installed in accordance with the Plans.

Support post and anchor locations are shown approximately in the Plans and will be approved by the Engineer prior to their construction. Anchors require a pullout capacity of 20,000 pounds, and at least 20% shall be proof tested. An anchor is acceptable if it sustains this load for 10 minutes with no loss of load. Anchors that fail this criterion shall be replaced and retested at the Contractor's expense. Testing shall be performed against a temporary yoke or load frame. No part of the yoke or load frame shall bear within 3 feet of the anchor.

The wire mesh shall be placed on the inside of the cable net panels, against the slope, and lapped and fastened as detailed in the Plans. With the exception of vertical seaming of the net panels, the wire mesh must be connected to the cable net panels as detailed in Plans prior to placement on the slope

Measurement
Modified cable net slope protection will be measured by the square foot.

Payment
The unit contract price per square foot for "Modified Cable Net Slope Protection" shall be full pay to perform the work as specified.

8/14/2007

CABLE NET SLOPE PROTECTION

Description

This work consists of installing and testing anchors and the placement of cable net panels backed with pvc-coated and colorized wire mesh in accordance with these specifications and the details shown in the Plans.

Submittals

Not less than two weeks prior to the placement of the cable net slope protection, the Contractor shall submit in writing to the Engineer for approval:

1. The supplier of the cable nets. The supplier must be a pre-approved provider of cable nets and included in the New Products list. Suppliers that are not pre-approved must provide written evidence that the cable nets have performed satisfactorily in similar capacities elsewhere.

2. The inclusive list and catalog cuts for the appurtenances to be used for the anchors, support system, and wire mesh fasteners (i.e., anchor bars, grout, wire rope, clips, thimbles, ferrules, steel rings, fasteners, etc.)

3. The color for the pvc-coated wire mesh.

4. The plan for installing anchors and verifying their capacity. The calibration data for the stressing device to proof test the anchors shall be provided. An independent testing laboratory shall have performed the calibration tests within 60 calendar days of the date submitted.

5. The plan for fabricating and placing the cable nets and wire mesh on the slope.

Work shall not begin until the Engineer has approved the appropriate submittals, in writing.

Materials

The cable net panels shall meet the following criteria:

Panel Size:	12 ft x 25 ft (approximate)
Grid Size:	no larger than 12 inch x 12 inch
Seam Rope:	no smaller than 5/16 inch diameter

Cable nets shall be braided with high strength, corrosion resistant clips made from a minimum 0.08 inch (2 mm) thickness plate. The clips shall be pressed on so as not to slip when manually stretched or during the placement of the nets. The clips must be secured in the manner intended by the manufacturer while not damaging the wire ropes. The Engineer shall reject even slightly damaged nets insofar as they could endanger the integrity of the system.

All wire rope shall be galvanized conforming to the requirements of ASTM A 603 Class A. The ¾ inch nominal wire rope shall be of independent wire rope class (IWRC) construction 6x19 and have a normal breaking strength of 52,900 pounds. The 5/16 inch nominal wire rope shall be of galvanized aircraft cable (GAC) construction 7x7 (or 7x19) having a normal breaking strength of 9,200 pounds, respectively.

The wire mesh used to back the cable net panels shall meet Section 9-16.4(2) of the Standard Specifications with the following revision:

> The phrase "*…3 ½ inches x 5 ½ inches diamond mesh chain link…*" shall be replaced with "*…2 inch chainlink or 8 x 10 double-twisted hexagonal wire mesh*".

The wire mesh shall be pvc-coated and colorized to match the surrounding ground conditions.

Hardware shall meet Section 9-16.4(4) of the Standard Specifications with the revision of being sized for ¾ inch diameter wire rope instead of ½ inch diameter wire rope.

Fasteners for attaching the wire mesh to the cable nets shall be of high tensile steel.

Anchors shall be one of those specified in the Plans, and all steel components shall be galvanized. Cement grout shall be proven, non-shrink materials capable of permanently developing the bond and internal strength necessary for the specified tensioning.

Corrosion protection paint shall conform to Section 9-08.2 for Formula A-9-73 - Galvanizing Repair Paint, High Zinc Dust Content.

Construction Requirements

Cable net slope protection shall be installed in accordance with the Plans.

Anchors shall be located a minimum of 15 feet beyond the slope crest. The Engineer shall approve each anchor location. Unless otherwise specified, anchors shall have a minimum vertical pullout capacity of 20,000 pounds. Vertical pullout testing shall be performed against a temporary yoke or load frame. No part of the yoke or load frame shall bear within 3 feet of the anchor. As an alternative, anchors can be tested in a horizontal direction or along the fall line of the slope. Anchors tested in this manner shall have a minimum capacity of 20,000 pounds achieved with no more than 12 inches of horizontal deflection after application of the initial alignment load of 500 pounds. For both verification tests, an anchor is acceptable if it sustains this load for 10 minutes with no loss of load. Anchors that fail this criterion shall be replaced and retested at the Contractor's expense. Up to 25 percent of the anchors shall be proof tested at the discretion of the Engineer for no additional compensation. If more than three anchors fail, the Contractor shall proof test all anchors for no additional compensation.

The wire mesh shall be placed on the inside of the cable net panels, against the slope, and lapped and fastened as detailed in the Plans. With the exception of vertical seaming of the net panels, the wire mesh must be connected to the cable net panels as detailed in Plans prior to placement on the slope

Measurement
Cable net slope protection will be measured by the square foot.

Payment
The unit contract price per square foot for "Cable Net Slope Protection" shall be full pay to perform the work as specified.

(******)
MOVEABLE ROCKFALL BARRIER ANCHORS

Description
This work shall consist of furnishing, installing and, testing, removing, and backfilling anchors for the Moveable Rockfall Barrier (MRB). Also included is moving the entire MRB assembly in order to shield the roadway from potential rockfall that may be generated by the construction activity see **Moveable Rockfall Barrier Special Provision**.

Design Criteria
For design purposes, the anchors subsurface consists of approximately 0.25' of HMA over 0.75' of Portland cement concrete pavement. Subsurface material below the cement concrete is unknown.

Anchor shall be capable of resisting the following minimum working loads after installation:

3000 lbs. Tension
7500 lbs. Shear

The Contractor is advised that the following equipment has been successfully utilized on a past WSDOT project to move (slide) the MRB from one position to another as the slope work progressed.

1) Howard Copper C Series 2 Track Hoe

The above is informational only and the Contractor is responsible for providing equipment capable of moving the MRB.

Submittals
The Contractor shall submit an anchor design to the Engineer 14 calendar days prior to beginning any slope work. The anchor design submittal shall include the anchor type, anchor diameter, minimum embedment depth, anchor installation and removal method, anchor hole patching methods and materials, manufacturer catalog cuts and all other pertinent data.

The Moveable Rockfall Barrier anchor system currently has 1-1/4 inch diameter holes for anchoring. If larger anchor diameter holes are proposed, the Contractor shall also include a modification plan for the MRB with the anchor submittal package.

Installation
Upon Engineer approval of the anchor design, the Contractor shall make any approved modifications to the MRB necessary for the anchor system. The Contractor shall be responsible for locating and installing the anchors and when no longer required shall remove them in accordance with the approved method.

Testing
The Contractor shall Proof proof test the initial anchor and a minimum of 20% of subsequent anchors under the observation of the Engineer as follows:

The anchor will be stressed to 1.25 times the design load and held for 10 minutes. The anchor shall be considered acceptable is no observable movement in the anchor head or loss of load as measured with calibrated hollow-ram hydraulic jack has occurred during the test period. All failed anchors shall be removed and replaced at the Contractor's expense.

The hollow-ram hydraulic jack will be provided by the Contractor and shall meet requirements set for the hydraulic jack used for testing the rock dowels and bolts.

Measurement

Moveable Rockfall Barrier Anchor will be measured per each installed and accepted.

Payment

Payment will be made in accordance with Section 1-04.1, for the following bid item:

"Moveable Rockfall Barrier Anchor", per each

The unit contact price per each accepted anchor shall be full pay for all costs to furnish, install, test, and remove and repair after each anchor. It shall also include and for modification to the MRB if required for proposed anchor system, and for moving the entire MRB assembly to the Engineer Engineer-approved locations.

8/20/2007

MOVEABLE ROCKFALL BARRIER

Description

This work shall consist of obtaining, assembling, and utilizing up to four Moveable Rockfall Barriers (MRB) owned by the Contracting Agency. After completion of the work, MRBs will be repaired and returned to the Contracting Agency. The MRBs will be used during all scaling work and anchor installation at the locations shown in the Plans or where otherwise designated by the Engineer.

Submittals

The Project Engineer has available for review detailed plans for the Moveable Rockfall Barriers (MRB) at the following location:

Project Engineer Office
address

Not less than two weeks prior to commencing the fence installation, the Contractor shall submit in writing to the Engineer for approval:

1. The proposed construction sequence and schedule.

2. The proposed ground anchor methods, materials and equipment necessary for their installation and verification testing. See Special Provisions **"Moveable Rockfall Barrier Anchors"**.

Work shall not begin until the Engineer has approved the appropriate submittals in writing.

Materials

All of the MRBs will be supplied by the Contracting Agency. The Contractor shall notify the Project Engineer and Contact Person a minimum of 24 hours before inspection and pick up the MRBs. Two systems area stored at each of the following locations (for a total of four complete systems):

WSDOT Materials Laboratory
1655 S. 2nd Avenue
Tumwater, WA 98512
Contact Person: Steve Lowell
360-709-5460

WSDOT Maintenance (Bullfrog)
151 South Bullfrog Road
Cle Elum, WA 98922
Contact Person: Terry Kukes
509-577-1907

Prior to use, the cable net panels must be backed by wire mesh acquired by the Contractor. The wire mesh shall consist of either 2-inch, 9 gage chainlink fabric or 8 x 10 size double-twisted hexagonal wire mesh.

Construction Requirements

The Contractor shall assemble the MRB in accordance with the Contracting Agency assembly instructions and the Plans.

The MRB shall be placed and secured to its foundation prior to performing any slope stabilization work, except as noted in the Traffic Control Plans.

The MRB shall not be removed or reset until slope stabilization work in that area has been approved by the Engineer.

The MRB shall be maintained and repaired as needed. Spot patching of the wire mesh will be performed as directed by the Engineer. Necessary repairs resulting from the stabilization work will be paid under Force Account as Repair Rockfall Safety Items.

At the conclusion of the slope stabilization work, all MRBs will remain the property of the Contracting Agency. The Contractor shall repair or replace any damaged sections of the fence system as designated by the Engineer paid under Force Account as Repair Rockfall Safety Items.

After completion of the work, the Contractor will disassemble the MRBs and remove the wire mesh backing. Disposition of the wire mesh backing will be the Contractor's responsibility and expense. The rockfall containment nets should be delivered to the pickup locations. The Contractor shall notify the Engineer and Contact Person a minimum of 24 hours before returning the MRBs.

Payment
Payment will be made in accordance with Section 1-04.1, for the following bid item:

"Moveable Rockfall Barrier", lump sum

The unit contact price Lump Sum for "Moveable Rockfall Barrier" shall be full pay for performing the work as specified, including pickup, assembly, the use during all on-slope stabilization work, disassembly, and return of the MRBs to the Contracting Agency.